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The role of public open spaces for physical activity promotion among adolescents

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SUMMARY

Sufficient physical activity is associated with several health benefits among adolescents. However, few adolescents comply with the physical activity guidelines of 60 minutes moderate- to vigorous-intensity physical activity daily. Therefore, interventions are needed to promote physical activity among adolescents. Public open spaces have been identified as suitable locations for physical activity. However, insight was needed into how public open spaces are currently used and which public open space characteristics could invite adolescents to engage in physical activity at public open spaces.

The first objective of this doctoral thesis was to gain insight into the current physical activity levels among European adolescents. Results indicated that more than half of the adolescents do not comply with the physical activity guidelines and there is a need for a pan-European surveillance system to monitor the changes in physical activity levels in the future.

The second objective of this doctoral thesis was to gain insight into the use of public open spaces in Flanders. Our results revealed that among adolescents, public transportation stops/stations were used frequently, whereas parks were rarely used. Within parks, trails and playgrounds were used most often and at highest energy expenditure. Additionally, the lower educated and those with a non-Western-European ethnicity used public open spaces more often and younger adolescents and boys were more likely to use public open spaces for physical activity than their counterparts.

The third objective was to gain insight into the characteristics of public open spaces associated with public open space use and physical activity. Our findings highlighted that public open spaces have to contain challenging features, sport fields and playgrounds and have to be well maintained. Additionally, the presence of undesirable users was discouraging, whereas active peers were encouraging for public open spaces visitation and physical activity.

The final objective was to develop an experimental study using manipulated photographs to identify the most important park characteristics influencing adolescents' park visitation and physical activity. Our results revealed that park maintenance was the most important factor for park visitation and physical activity, followed by the presence of a playground/outdoor fitness equipment and a sport field.

Our results emphasize the need for interventions targeting public open space and park use among adolescents. These interventions should especially target girls and older adolescents. Additionally, urban planners should attempt to create public open spaces that are more attractive for adolescents by installing sport fields, outdoor fitness equipment and playgrounds. Furthermore, park administrators should invest in frequent and profound maintenance systems in order to provide well maintained parks.

SAMENVATTING

Men heeft reeds aangetoond dat voldoende fysieke activiteit geassocieerd wordt met verscheidene gezondheidsvoordelen bij jongeren. Jongeren zouden 60 minuten per dag aan matige- tot hoge intensiteit moeten bewegen, maar slechts weinig jongeren halen deze norm. Openbare ruimtes zijn locaties die geschikt kunnen zijn voor fysieke activiteit bij jongeren. Er was echter, bij de start van dit doctoraat, nog niet veel geweten over het gebruik van openbare ruimtes in België en Europa. Bovendien was er nood aan meer inzicht over de kenmerken van openbare ruimtes die jongeren kunnen aanmoedigen om openbare ruimtes te bezoeken en te gebruiken voor fysieke activiteiten.

Het eerste doel van deze doctoraatsthesis was om inzicht te verwerven in de mate van fysieke activiteit bij jongeren in Europa. De resultaten van ons onderzoek toonden aan dat meer dan de helft van alle jongeren te weinig fysiek actief is. Bovendien is er dringend nood aan een overkoepelend Europees systeem om de veranderingen in fysieke activiteit bij jongeren te kunnen opvolgen.

Het tweede doel was om na te gaan hoe openbare ruimtes gebruikt worden in Vlaanderen (België). Met andere woorden, welke soorten openbare ruimtes worden gebruikt en door wie? Onze resultaten toonden aan dat jongeren voornamelijk tijd spenderen op “openbaar vervoer locaties” zoals bushaltes en stations, terwijl parken slecht sporadisch gebruikt worden. In parken zijn de paden de zones die het meeste gebruikt worden en aan de hoogste intensiteit. Bovendien vonden we dat lager opgeleide adolescenten en adolescenten met een niet-westerse etniciteit meer gebruik maakten van openbare ruimtes en dat jongere adolescenten en jongens openbare ruimtes vaker gebruikten voor fysieke activiteit.

Het derde doel was om te bepalen welke kenmerken van openbare ruimtes jongeren kunnen aanmoedigen of ontmoedigen om een openbare ruimte te bezoeken of er actief te zijn. Ons onderzoek toonde aan dat jongeren goed onderhouden openbare ruimtes met uitdagende speeltuigen, fitnesstoestellen en sportveldjes, aantrekkelijk vinden om te bezoeken en voor fysieke activiteit. Bovendien werden openbare ruimtes waar vreemden (zoals druggebruikers en daklozen) aanwezig waren, als minder uitnodigend bevonden, terwijl openbare ruimtes waar andere jongeren fysiek actief waren net wel aantrekkelijk werden bevonden om te bezoeken en er fysiek actief te zijn.

Het laatste doel van deze doctoraatsthesis was om een foto-experiment uit te voeren om na te gaan welke kenmerken parken aantrekkelijk maken voor jongeren om ze te bezoeken en er actief te zijn. Het onderhoud van het park was het belangrijkste kenmerk voor de aantrekkelijkheid van een park, gevolgd door de aanwezigheid van fitness toestellen/ speeltuigen en sportveldjes.

Onze resultaten benadrukken het belang van interventies die het gebruik van en fysieke activiteit op openbare ruimtes aanmoedigen. Zulke interventies zouden vooral gericht moeten zijn op meisjes en oudere adolescenten. Voorts zouden stedenbouwkundigen openbare ruimtes moeten creëren die aantrekkelijk zijn voor jongeren, en dus sportveldjes, fitness toestellen en leeftijdsgeschikte-speeltuigen bevatten. Park verantwoordelijken (voornamelijk steden en gemeenten) zouden moeten investeren in degelijke, regelmatige en uitgebreide onderhoudssystemen om zo te kunnen garanderen dat de parken goed onderhouden zijn.

PART 1: GENERAL INTRODUCTION

1. PHYSICAL ACTIVITY IN ADOLESCENCE

1.1. DEFINITIONS

1.1.1. ADOLESCENCE

Currently, there is no standard definition of adolescence. The World Health Organisation defines adolescents as those people between the ages of ten and nineteen years old [1]. However, adolescence has been defined as "the transition from the dependence of childhood to adulthood independence" by the United Nations [2]. In this doctoral thesis, 12- to 16-year-old adolescents were the population of interest. Youth aged 12-16 years differ from older and younger youth because of physical changes of the body, personality development and puberty [3,4]. Additionally, this period corresponds to the transition from primary school to secondary school and before the possibility of obtaining a driver's licence (for a moped) and gaining more independent mobility compared to children (Part 1: General Introduction: chapter 3.4).

1.1.2. PHYSICAL ACTIVITY

The World Health Organisation defines physical activity as "any bodily movement produced by skeletal muscles that requires energy expenditure. This includes activities during school hours, while working, playing or during recreation" [5]. Four domains have been identified, in which physical activity can take place: active transportation, occupational/school physical activity, household activities and active recreation [6]. Physical activity can be classified according to intensity level: light-, moderate- or vigorous-intensity physical activity. The intensity of physical activity is often expressed as the metabolic equivalent value of the activity (MET) whereby one MET represents the energy needed in rest. Light-intensity physical activity, corresponds to activities between one and three METs, activities with a value of three to six METs are defined as moderate-intensity physical activity and vigorous-intensity physical activities are all activities with a MET value higher than six [7]. Adolescents should engage in 60 minutes of moderate- to vigorous-intensity physical activity daily in order to obtain health benefits. Within these 60 minutes, vigorous-intensity physical activity and activities that strengthen muscle and bone should be incorporated at least three times per week [8]. Physical inactivity is defined as not meeting the physical activity recommendations of 60 minutes of moderate- to vigorous-intensity physical activity daily [8,9].

Physical activity should not be mistaken with physical exercise or physical fitness. Physical exercise has the goal to improve or maintain physical fitness and is one part of physical activity

that is planned, structured and repetitive [10]. Physical fitness can be defined as “a state, characterized by (1) the ability to perform daily activities and (2) the demonstration of characteristics and capacities that are associated with low risk of premature development of diseases associated with physical inactivity” [11].

Another construct that has gained interest in the last decade is sedentary behaviour, which has been defined as: “any waking behaviour characterized by an energy expenditure ≤1.5 METs, while in a sitting, reclining or lying posture” [12]. The terms sedentary behaviour and physical inactivity have been used interchangeably in the past, however a clear distinction can be made as physical inactivity refers to insufficient levels of physical activity while sedentary behaviour refers to sitting or lying behaviours. For example, an adolescent that adheres to the physical activity guidelines of 60 minutes of moderate- to vigorous-intensity physical activity daily, can still spend the remaining time sedentary, and can therefore be classified as physically active with high levels of sedentary behaviour.

1.2. Measurement of physical activity

Physical activity is a complex behaviour that can take place in four domains (occupational/school, home, transportation and leisure time). Depending on the sample size and research questions that are addressed, different methods can be used to asses physical activity [13].

1.2.1. Self-reported physical activity

The most commonly used self-report measurement methods are self-administered questionnaires, interview-administered questionnaires and diaries [13-16]. Self-report methods are the cheapest and easiest methods to measure physical activity in large populations. Another major advantage of self-report methods is that information can be obtained on specific physical activity behaviours and domains (e.g., cycling for transport) [14,16]. However, these self-report methods pose multiple limitations due to the nature of physical activity behaviour, such as: recall bias, social desirability bias, poor respondent motivation, difficulties in defining frequency, exact duration and intensity, difficulties to capture physical activity in all domains [13,14,16] and a large burden for participants (diary)[17].

In an extensive review on the validity and reliability of physical activity questionnaires for youth, none of the included questionnaire showed acceptable validity and reliability [18] while another review identified four questionnaires (e.g., Flemish physical activity computerized questionnaire) with acceptable validity and reliability [19]. This indicates that results from studies using questionnaires have to be interpreted with caution.

1.2.2.OBJECTIVELY MEASURED PHYSICAL ACTIVITY AND DIRECT OBSERVATION

The most commonly used objective physical activity measurement methods are heart rate monitors, accelerometers and pedometers [14,20]. The main limitations of these objective measurement methods are the inability to provide contextual information, high costs of accelerometers and heart rate monitors, and difficulties with accelerometer data processing [20,21]. Additionally direct observations are also used to estimate physical activity [14,20]. The biggest limitation of direct observations is the high burden on the researchers [20,21].

Direct observation poses a high burden on the burden on the researchers, requires trained researchers and provides only a momentary assessment of physical activity levels, but it is a method that is particularly interesting to use when investigating physical activity at a certain location [14,17] (e.g., in parks). Accelerometers capture real time physical activity levels, measure frequency, duration and intensity of physical activity behaviour [20,21]. Accelerometers measure acceleration in one or more planes and convert it to quantitative measures, called counts [13,22]. Recently researchers have been moving towards a consensus on which cutpoints to use to categorize accelerometer counts into different physical activity intensities (sedentary behaviour, light-, moderate- and vigorous-intensity physical activity) for children and adolescents [23]. Nevertheless many uncertainties exist concerning data processing. Additionally, accelerometers are not able to capture specific activities such as swimming or cycling [20,22]. Pedometers are less expensive and are therefore often used in large population studies, however, they only provide a measure of step counts and do not estimate activity intensity [20,21]. Heart rate monitors consist of a chest wrap monitor, often combined with a wristwatch to display the heart rate. The linear relationship between heart rate and oxygen consumption is used to estimate physical activity levels. Heart rate monitors are not suitable to measure water activities and heart rate can also be influenced by emotions, fitness and temperature [16,17,20].

Heart rate monitors, accelerometers and pedometers do not provide information on the location or the domain (school/occupation, active transportation, leisure time, home) where physical activity takes place. However, when combining these methods with a Global Positioning System (GPS) device, location-specific physical activity can be assessed. Location-specific physical activity measurements are needed in order to develop effective interventions. Furthermore, ecological models emphasize the need to consider location specific physical activity, as it is hypothesized that different types of locations facilitate diverse physical activity behaviours [6,24]. During the last decade, accurate, low-cost and lightweight GPS devices have been developed. These new affordable devices have enabled research using this methodology, however, the number of studies using GPS devices in combination with accelerometers is still rather limited [21,25-27]. Additionally, in order to obtain information about the domain (recreation vs transportation) in which the physical activities are performed, self-report measures are necessary. In conclusion, to obtain an accurate estimate of location- and domain-specific physical activity levels, it is recommended to use objective measurement methods combined with self-report methods and GPS devices.

Next to these more traditional scientific measurement methods, currently also consumer wearable activity trackers (such as Fitbit) are being used. These are electronic devices usually used to monitor fitness activities. However, only for the step count measure, acceptable validity was found, whilst no evidence was found for physical activity, energy expenditure and sleep [28,29]. Currently it is not advisable to use these kinds of physical activity trackers for scientific purposes because of the low validity.

1.3. Physical activity and health

Sufficient physical activity (i.e. 60 minutes daily) has been shown to be associated with health benefits during adolescence. Several systematic literature reviews have indicated that sufficient physical activity is related to multiple health outcomes: a lower amount of body fat [30,31], lower Body Mass Index (BMI) [31], better cardiopulmonary fitness and physical fitness [30], higher peak bone mass and bone health [30,32], cardio metabolic biomarkers [30,31], better mental health, self-esteem and quality of life/well-being [30-32], and less depressive symptoms [31,32]. Furthermore, a dose response relationship was identified, indicating that the more physical activity, the greater the health benefits [33]. Additionally, it has been shown that child and adolescent physical activity levels track into adulthood, i.e. high physical activity

levels during childhood and adolescence can track and lead to high levels of adult physical activity [34,35]. Therefore, it is of utter importance to incorporate healthy physical activity habits into the daily lives of children and adolescents. Furthermore, Hallal et al. (2006) suggested a possible direct influence of adolescent physical activity levels on adult health [32], however this relationship has not yet been confirmed.

1.4. Physical activity levels among adolescents

A steep decline in physical activity levels has been found during the transition from primary school to secondary school (around the age of twelve). Subsequently, adolescent physical activity levels are lower compared to physical activity levels among children [36]. A significant average decline in physical activity levels of 7.0% per year, was reported in a systematic review by Dumith et al. (2011), where data from 26 studies were pooled (mean age at baseline: 12.4 years old; and follow up: 16.0 years old). Additionally, in recent studies (included in that systematic literature review), this decline tended to be greater for girls compared to boys [37].

Hallal et al. (2012) aimed to describe worldwide physical activity levels among adults and youth in order to identify patterns and regional differences. They concluded, based on two questionnaire based studies, that 80% of 13- to 15-year-old adolescents worldwide did not comply with the physical activity recommendations, and that large differences exist between countries [38]. These differences between countries could be caused by cultural differences or different physical activity policies.

In 2010, a report was published by the World Health Organisation containing an overview of existing national and international studies on physical activity levels in Europe [39]. In this report it was concluded that it was not possible to compare nationally generated physical activity data because of the different measurement methods that were used across different national studies. Based on data from the international HBSC (Health Behaviour in School aged Children) study, it was concluded that the prevalence of adherence to the physical activity guidelines ranged from 12% to 51% among 11-year-olds. However, in the report from the World Health Organisation no country-specific data were reported, hindering comparison between countries [39].

From these previous studies we can conclude that worldwide adolescents' physical activity levels are low, and differences between countries exist. This emphasizes the importance of

research on how to counteract this decline in physical activity levels during adolescence, accounting for country-specific differences. As discussed in chapter 1.2 (Part 1: General Introduction), physical activity levels may differ according to the measurement methods used. However, up to now, no report or systematic literature review has been able to present country-specific physical activity prevalence data for European adolescents while accounting for the measurement methods that were used.

Given the shortcomings of previous studies (i.e. only subjective data in the study by Hallal et al. (2012) [38] and no country-specific data in the report from the World Health Organisation [39]), an update of the European physical activity prevalence data among youth is warranted. Europe is a very heterogeneous region with diverging climates, cultural habits and policies. Therefore, a clear overview of the current physical activity levels in Europe is needed in order to monitor the decline in physical activity levels that has been found among youth. Additionally, it is needed to gain insight into the methods currently used to measure physical activity, in order to harmonize these measurement methods by developing a pan European monitoring system. Therefore, within this doctoral thesis a systematic literature review was performed which aimed to provide an overview of the existing cross-European studies (i.e. with more than one European country) that monitor adolescent physical activity levels, to report country-specific physical activity prevalence data and to define the challenges posed by the measurement methods that are used.

2. DETERMINANTS OF PHYSICAL ACTIVITY: A SOCIO ECOLOGICAL APPROACH

In order to increase physical activity levels among adolescents, insight into the determinants of adolescents' physical activity is needed. Given the limited success of individually-oriented models to explain physical activity behaviours, socio-ecological models have been used to gain insights into the determinants of physical activity behaviours. According to socio-ecological models of health behaviour, physical activity is influenced by intrapersonal (individual), interpersonal (sociocultural), environmental (social and physical environment) and policy-related factors and the interactions between these factors [6,40]. These models emphasize that in order to increase physical activity at the population level, supportive environments and policies should be created, social norms and social support should be strong and individuals should be motivated to make healthy physical activity choices [40]. The socio-ecological model that was created by Sallis et al. (2006) [6] consists of different levels, which are presented around four domains of active living, i.e. active recreation, physical activity at home, active transportation and occupational/school physical activity (Figure 1). This doctoral thesis will focus on the domain of active recreation. Few studies however, have focussed on this domain. Additionally, most studies have used many different methods which made it hard to draw conclusions. Therefore, also studies examining determinants of adolescents' total physical activity are included in the introduction of this doctoral thesis.

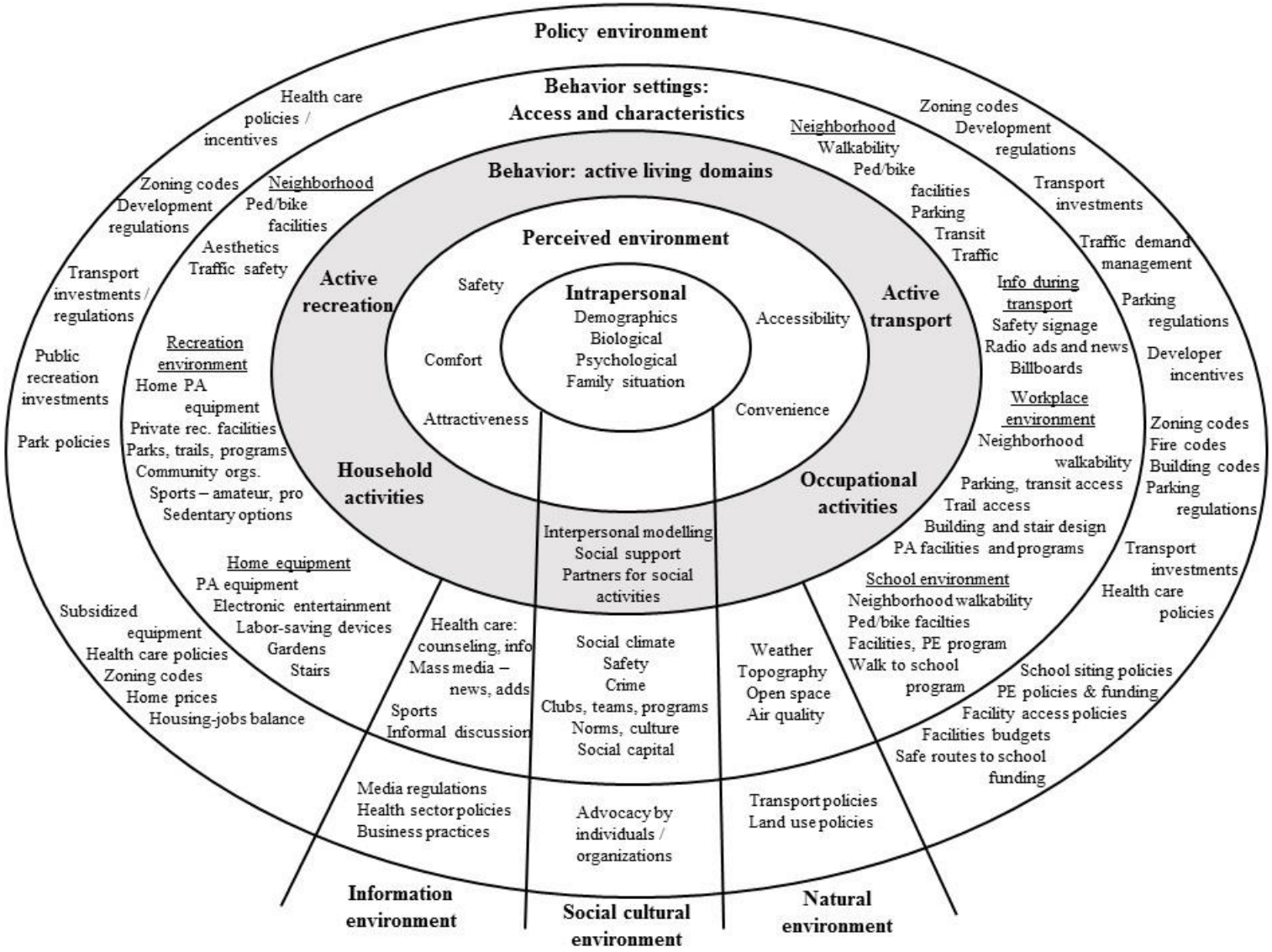

Figure 1: Ecological model of four domains of active living [6]

2.1. Intrapersonal level

Within the model presented by Sallis et al., (2006) the core of the model represents the individual factors that can influence physical activity levels. Research that focusses on non-modifiable individual factors such as gender, contributes to the evidence on the sub groups at risk for physical inactivity. These subgroups have to be targeted during interventions [6].

Several systematic literature reviews have indicated that 12- to 18-year-old adolescent boys have higher levels of overall, moderate- to vigorous-intensity and vigorous-intensity physical activity compared to adolescent girls [41-43]. Furthermore, an inverse association between age and overall, moderate- to vigorous-intensity and vigorous-intensity physical activity has been found in several systematic literature reviews [42-44], indicating that as adolescents grow older, physical activity levels decline.

Adolescents' socio-economic status (SES) is often measured by family income, parental education or occupational status. A higher parental educational level [41,43,45] and family income [45] have been shown to be associated with higher overall physical activity levels among 12- to 18-year-old adolescents, but not in children younger than 12-years-old. This indicates that after the transition to adolescence, those with lower financial resources may be more restricted in their physical activity opportunities. Findings on the relationship between 12- to 18-year-old adolescents' overall physical activity and BMI [41], body weight, adiposity [43] and ethnicity [41,43] are inconsistent.

The psychological factors that have consistently been identified as positively associated with 12- to 18-year-old adolescents' total physical activity are achievement orientation (i.e. academic achievement) and perceived competence [43]. For attitude, self-efficacy, motivation, intention, perceived barriers, perceived benefits, fun/enjoyment and depression, results are inconclusive [41,43]. Previous studies found no associations between total physical activity and self-perception or self-esteem [41,43].

2.2. Interpersonal level

The interpersonal level comprises the relationships between people. According to three systematic literature reviews, parental and peer modelling were not related to 12- to 18-year-old adolescent' total physical activity levels [41,43,45]. Family and peer support [41,43,44,46]

were consistently positively related with 10- to 18-year-old adolescents' total physical activity levels. Furthermore, in a longitudinal study, peer norms have been shown to predict activity intention among 13- to 17-year-old adolescents [47].

2.3. ENVIRONMENTAL LEVEL

2.3.1. SOCIAL ENVIRONMENTAL LEVEL

A study has identified friends and classmates as the people most often accompanying 11- to 16-year-old adolescents for physical activity in general [48], whereas among younger children (9- to 13-years-old) physical activity most often took place with multiple people together (e.g., friends and family) or with family [49]. Furthermore, Salvy et al. (2012) reported that adolescents were more likely to report physical activity at higher intensity when they were in the company of a friend compared to when they were alone [50]. Furthermore, a Brazilian study has shown that 14- to 19-year-old adolescents, living in neighbourhoods where other adolescents are physically active, are more likely to be physically active themselves compared to adolescents living in neighbourhoods where no other adolescents are active [51]. A Portuguese study found similar results, but only among boys (12- to 18-years-old) [52]. Therefore it could be concluded that the company of friends and the presence of active peers could be associated with adolescent physical activity levels, however research remains limited.

Feelings of safety are influenced by many social and physical environmental factors, for clarity, all safety related determinants (social and physical) will be discussed in the following section. When 12- to 18-year-old adolescents perceive their neighbourhood to be safe, and when objectively measured crime rates are low, adolescents' overall physical activity, outdoor physical activity during leisure time and organized physical activity levels are higher than when adolescents live in neighbourhoods that are perceived unsafe with high objectively measured crime rates [45,53-55]. Furthermore, the presence of undesirable users, such as homeless people, people drinking or drug users in parks, has been indicated in qualitative research as negatively associated with physical activity levels in parks [56]. Quantitative studies found no association between 13-year-old adolescents' concern about strangers/older youth and walking and cycling in their neighbourhood, even though more than 30% reported concerns about strangers [57]. Nevertheless, physical evidence of the presence of undesirable users of

a place (e.g., graffiti, empty beer bottles) was negatively associated with total physical activity levels [54,58].

2.3.2. PHYSICAL ENVIRONMENTAL LEVEL

The physical environment has been defined as "the objective and perceived characteristics of the physical context in which adolescents spend their time including aspects of urban design (e.g., presence and structure of sidewalks), traffic density, traffic speed, distance to and design of venues for physical activity (e.g., playgrounds, parks and school yards), crime, safety (described above) and weather conditions" [54]. The physical environment consists of the natural environment (i.e. plants, trees, the weather) and the built environment (i.e. all elements that are created or modified by people, such as buildings and streets). Socio-ecological models have identified the home, school, recreation and neighbourhood environment as most important physical environments for physical activity [6].

The review of Davison et al. (2006), studying the relationship between the built environment and child and adolescent physical activity, reported that four out of six studies found no association between home physical activity equipment and adolescents' total physical activity levels. Whereas two studies among a predominantly white sample found that the number of pieces of exercise equipment was positively associated with total physical activity [54]. Within the school environment, lower distance to school and the availability of sports equipment at school were associated with higher levels of total physical activity [54], whereas the provision of school physical activity facilities was unrelated to total physical activity [45]. Considering the neighbourhood environment, the review of Ding et al. (2011) reported land use mix and residential density as the most supported correlates for total physical activity, recreational physical activity and transport related physical activity among 13- to 18-year-old adolescents. Whereas no associations or inconsistent results were found for street connectivity and traffic speed [59]. A lot of research has focused on the relationships of the accessibility and availability of parks, recreational facilities and playgrounds in the neighbourhood with adolescents' physical activity. As public open spaces are the focus of this doctoral thesis, these will be discussed in detail in chapter 3.6 (Part 1: General Introduction).

3. URBAN PUBLIC OPEN SPACES

3.1. DEFINITION

There is a lack of uniformity in the definitions of public open space that are used in environmental research [24]. Public open spaces are sometimes defined as green spaces and natural environments, (e.g., Edwards et al. (2013) defined public open space as "spaces reserved for the provision of green space and natural environments, accessible to the general public free of charge" [60]), and sometimes as spaces designed especially for recreational purposes (e.g., the National health foundation of Australia (2014) defined public open space as "a variety of spaces within the urban environment that are readily and freely accessible to the wider community, regardless of size, design or physical features and which are intended primarily for amenity or recreation purposes, whether active or passive" [61]). These definitions are rather narrow and exclude non-green public open spaces such as squares and streets or spaces that are not designed for recreation such as vacant lots. Because of these narrow definitions, opportunities are missed to study a wider range of public open spaces and, consequently, there is a lack of research on the influence of different types of public open spaces on physical activity [24]. Therefore, based on these previous definitions and literature, a more comprehensive definition was developed. In this doctoral thesis, public open spaces are defined as follows: A public open space is a public space with open access, that is accessible to all people independent of age, ethnicity, physical limitations, or other characteristics [62-64]. Some public open spaces are under public ownership and management whereas others are private property but freely accessible and, therefore, also defined as a public open space [64,65]. Public open spaces can have different appearances such as parks, playgrounds and squares, but also streets, vacant lots and parking lots. This definition implies that public open spaces can be both indoor (e.g., a library) and outdoor spaces (e.g., a park). In this doctoral thesis only outdoor public open spaces were included, hence most indoor public open spaces are not suitable for physical activity or require entrance fees (e.g., indoor swimming pool).

Some differences exist in the availability and quality of public open spaces according to the location (i.e. urban versus rural). For example, in a Canadian study among 10- to 11-year-old participants, parents living in rural areas were less likely to report good parks in their neighbourhood compared to parents living in urban areas [66] and an Australian study found

that rural parks scored higher concerning aesthetics and the number of activity areas whereas urban parks scored higher on playground equipment, and the number of courts/ovals [67,68]. The subject of this doctoral thesis was limited to urban public open spaces, in order reduce variation due to differences between urban and rural public open spaces. In this doctoral thesis, the difference between urban and rural areas was defined as follows: municipalities with less than 300 inh/km² = rural, 300-600 inh/km² = suburban, and more than 600 inh/km² = urban [69].

3.2. Recent demands of urban public open space

The number of people living in urban areas has increased up to more than half of the world population and is predicted to rise up to 66% by 2050 [70]. This will lead to the expansion and densification of cities and will enlarge the need for urban public open space, increase the importance of public open space for society, and change the demand and use of public open spaces. In line with this, the provision of good, qualitative and accessible public open spaces has received increased attention by the United Nations. After the Rio+20 United Nations Conference on sustainable development in 2012, a declaration was published on "The future we want". In this declaration, the United Nations have made the commitment to promote an integrated approach to planning and building sustainable cities and urban settlements, including the promotion, protection and restoration of safe and green urban spaces, because of the growing importance of these spaces [71].

In the nineteenth century, public open spaces were designed as a place where people could practice politics and as a place for physical recreation [72]. However, the demand of public open space in the 21st century may have changed due to changing lifestyles, more ethnical and cultural diversity in cities, new technologies and climate change. For example, public open spaces are essential for real-life social interactions (as opposed to online contacts) [72] and for access to green spaces [72]. Furthermore, it is hypothesized that the densification of cities will lead to a decrease in private green spaces (i.e. less people will have access to a private garden), although access to green spaces has been identified as a fundamental need for health [72]. Exposure to greenspaces has been shown to affect mental and [73] general perceived health [74], can be restorative (i.e., when they give users a sense of being away from their usual setting) [75,76] and provides opportunities to socialize [77]. Public open spaces can

provide access to green spaces within urban areas, however, it has been suggested that these green spaces do not have to be formal parks, but can also consist of more “loose-fit” places such as vacant lots [72,78]. Recently, the importance of public open spaces in the development of sustainable ecosystems [79], water management systems (i.e. to prevent floods) [80] and to counteract the urban heat island effect (i.e. the phenomenon where the air temperature in urban areas is higher than in the surrounding rural environment) [81] has been acknowledged.

Public open spaces are important places for adolescents because they provide some kind of private space (without adult supervision). Adolescents who are in the transition to adulthood can use public open spaces to try out and practice adult behaviours. Public open spaces provide a place for story-telling and meeting peers [82] and act as a space where they can build cultural identity [83].

3.3. Measurement of public open space characteristics

The availability and quality of public open spaces can be measured using self-report measures (i.e. questionnaires), observational measures such as audit tools or objective methods such as Geographical Information Systems (GIS).

Perceptions of public open space availability and quality are often measured using questionnaires that focus on the neighbourhood environment. These questionnaires usually include questions on the presence of recreational facilities or parks, traffic safety and aesthetics of the neighbourhood [84]. However, to gain more detailed information on public open space characteristics, audit tools can be used to systematically map the presence and quality of public open space features. Audit tools are mostly used to measure physical features that cannot be captured using GIS or aerial photographs [85], such as the level of maintenance, sidewalk width or number of trees in a street [84]. GIS is a framework that integrates information from existing data sources that have some spatial reference [84,86]. GIS can store, manage, and geographically integrate large amounts of information, and enables the mapping of health events (e.g., physical activity levels) in relation to their environment (e.g., availability of public open spaces) [87]. GIS is often used for more general measures of public open spaces, such as land use mix, access to recreational facilities, crime or street patterns [84], and makes it possible to obtain precise spatial measures such as, distance from home to a park [86].

3.4. Importance and current use of public open spaces for physical activity

In 2014, at the start of this doctoral thesis, little was known about the use of public open spaces in Europe and the availability, accessibility or the characteristics of public open spaces related to public open space visitation and physical activity. Therefore, in the following sections, an overview of the existing literature before the onset of this doctoral thesis is provided. Studies among all age groups will be described, but particular attention will be awarded to those focusing on adolescents.

Public open spaces are important for mental and physical health by providing a place for recovery and a location for physical activity. Public open spaces can play an important role in promoting physical activity among people of all ages, as public open spaces are present in most communities and are generally free to use [88-90]. Public open spaces have been shown to be highly used for physical activity and recreational activities [91]. For example, parks are frequently used for physical activity by people of all ages [92]. Physical activity at public open spaces can be estimated by using direct observation when one specific location (e.g., a park) is studied or by using questionnaires or a combination of accelerometers and GPS devices when overall use of public open spaces and physical activity is studied (see Part 1: General Introduction: chapter 1.2). A US study aiming to identify the locations where 11- to 12-year-old children engaged in physical activity using GPS and accelerometers found that outdoor public open space use varied by season. Most street use was recorded during spring whilst most playground and park use took place during summer. Additionally, it was found that 30% of children's daily physical activity levels was accumulated at streets and 8% at parks or playgrounds [93]. A UK study using GPS and accelerometers revealed that only 13% of 10- to 11-year-old children's time was spent outdoors during which 30% of all physical activity was accumulated. Furthermore, 5% and 7% of their daily physical activity was accumulated in green spaces for girls and boys, respectively [94]. A large US time-survey study also revealed that most of adolescents' physical activity was accumulated outdoors, away from home (42%) [49]. Moreover, studies from Australia and the UK have shown that park [95] and public open space [96] users are more likely to comply with the physical activity recommendations.

Furthermore, public open spaces can be a destination to walk or cycle to (even if people engage in sedentary activities after arriving at the public open space) and thereby increase

overall physical activity levels [90]. Especially for adolescents, public open spaces can be a promising setting for organized and non-organized physical activity, since they do not have the possibility to obtain a driver's licence (and are therefore more designated to the close neighbourhood compared to adults) and have more independent mobility (i.e. ability to roam in the neighbourhood without adult supervision) compared to children [97].

Some observational studies conducted in parks in the US have shown different use of parks according to individual characteristics such as gender or ethnicity. Parks were mostly used by white people, children and men [98,99]. However, research from Europe is lacking. Furthermore, it was found that different park areas such as open fields, playgrounds and sport fields were used by different age groups whilst activity levels differed according to the park areas that were used (see further in Part 1: General Introduction: chapter 3.6). This indicates that different age groups make use of different park zones and each zone can elicit different physical activity levels.

Given that 1) public open spaces can provide a suitable location for physical activity, 2) most research originates from the US, 3) there is overall limited knowledge on the use of public open space locations, and 4) it has been shown that individual differences exist concerning the use of parks, it is clear that there is a need for more research into the current use of public open spaces in Europe, taking individual differences into account.

3.5. Availability and accessibility of public open spaces and the relation with physical activity and active transportation

The terms "availability" and "accessibility" of public open spaces are often used interchangeably. The "availability of public open spaces" indicates the amount of public open space that is present in a certain area such as a neighbourhood. The term "accessibility of public open spaces" includes different aspects such as proximity (i.e. distance to public open space), ease to reach (e.g., good sidewalks, not too much intersections), safety to reach (e.g., presence of pedestrian crossings) and the amount of public open space close by. The availability and accessibility of public open spaces have often been associated with higher levels of total physical activity, leisure time physical activity and active transportation across all ages.

Studies about the association between accessibility or availability of public open spaces and physical activity are divergent due to the different outcomes that are studied (i.e. total daily physical activity, leisure-time physical activity, total moderate- to vigorous-intensity physical activity). The availability and accessibility of public open spaces has been shown to be positively associated with physical activity among all age groups: availability of parkland and beaches showed positive associations with meeting physical activity guidelines among adolescents and adults [100], the number of playgrounds was positively associated with boys' (8- to 9-years-old) moderate- to vigorous-intensity physical activity in the weekend [101], the perceived availability of free- or low-cost recreational facilities was positively associated with self-reported leisure time physical activity among adolescent girls [52] and a systematic literature review has shown accessibility and availability of recreation centres to be associated with higher levels of adolescent total physical activity [54]. However, other systematic literature reviews have reported no association between availability and accessibility of public open spaces and adolescent total physical activity [41,45,89]. These inconsistent results are supported by an extensive literature review by Ding et al. (2011) on general neighbourhood characteristics and physical activity among youth, which reported that accessibility and availability of parks and recreation facilities, had inconsistent relationships with total physical activity, recreational physical activity and transport related physical activity among youth [59]. An overview of the systematic literature reviews investigating the association between the availability and accessibility of public open spaces and physical activity is given in Table 1.

Table 1: Overview of Systematic literature reviews regarding the availability and accessibility of public open spaces and the relation with physical activity.

Reference	Inclusion criteria	Databases	Public open space	Population	Outcome studied	Specific POS studied	Number of studies with direction of the association			Conclusion
							Positive	Mixed or no association	Negative	
Davison et al. 2006 [54]	Peer-reviewed articles and reports	PubMed, PsychInfo, EBSCO, CINAHL, TRANSPORT	Playgrounds, parks and recreation centres	Youth (3-18 years old)	Physical activity behaviours	Proximity of playgrounds and parks	1 (PE AR) 1 (PE CR) 1 (OE)	2 (PE AR) 1 (PE CR)		Association remains inconclusive
						Availability of recreation centres	1(PE AR) 5 (PE CR) 2 (OE)	1 (PE AR) 1 (PE CR)		Positive association
Ferreira et al. 2007 [45]	Peer-reviewed articles (1980-2004)	MedLine (PubMed), PsycInfo, Web of Science, EMBASE Sport-Discus	PA facilities/programmes	Youth (3-18 years old)	A measure of PA	Access/availability to PA facilities/programmes (3-12 years old)	3	17	0	No association found
						Distance to PA facilities (12-18 years old	0	1	1	No association found
						Access/availability to PA facilities/programmes (12-18 years old)	11	32	2	No association found
Kaczynsky et al. 2007 [89]	Peer-reviewed articles (1998-2005)	PsycInfo, PubMed, LeisureTourism Abstracts Web of Science	Parks and recreation settings (trails, open space, recreation centres, exercise facilities, sport facilities, golf courses, swimming pools, lake/beach/coast)	Adolescents (12-18) and adults (18+)	PA	Presence of parks and recreation settings	28	15	17	Association remains inconclusive
						Proximity of parks and recreation settings	15	15	11	Association remains inconclusive
Van Der Horst et al. 2007 [102]	Peer-reviewed articles	Pubmed and PsycINFO	Sport and recreational facilities	Youth (4-18 years old)	Overall PA	Availability of facilities adolescents	2	0	6	No association found

	(1998-2005)					Availability of facilities Children	0	0	7	No association found
Ding et al. 2011 [59]	Peer-reviewed articles before 2010	Active living research database (Pubmed, Web of Science, SPORTDiscus	Parks and recreation settings	Youth (3-18 years old)	Objectively measured total, recreational or transport PA	Parks (access/density/proximity)	23	30	0	Association remains inconclusive
						Recreation facilities (access/density/ proximity)	7	10	0	
					Subjectively measured total, recreational or transport PA	Parks (access/density/proximity)	4	8	0	
						Recreation facilities (access/density/ proximity)	11	0	0	

POS = Public Open Space, PA = Physical Activity, PE = Perceived Environment, AR = Adult Report, CR = Child report, OE = Objective Environment

Besides physical activity at public open spaces, active transportation to public open spaces can also contribute to overall physical activity levels. Therefore, availability and good accessibility of public open spaces could be important to increase active transportation levels. It was found that 10- to 12-year-old Australian children who perceive limited accessibility and availability of parks or sport fields in the neighbourhood were less likely walk or cycle for transportation [103]. Additionally, Australian 13-year-old adolescents living in a neighbourhood with high (parent-reported) perceived availability of sport facilities tended to report more cycling for recreation (girls), cycling for transport (boys) and walking with a dog (girls) [57]. Perceived and objective measures of accessibility and availability of public open spaces in Australia [91,96,104] and a community walking trail in the US [105] have been shown to be associated with transport, and recreational walking among adults and the availability of green- and recreational spaces (especially sportsgrounds and parks) has been associated with recreational cycling among adults in the Netherlands [106]. An overview of the peer reviewed articles investigating the association between the availability and accessibility of public open spaces and active transportation is given in Table 2.

Table 2: Overview of peer reviewed articles regarding the availability and accessibility of public open spaces and the relation with walking and cycling.

Reference	Country	Design	Public open space	Population		Outcome studied	Specific POS characteristic studied	Direction of the association		
				N	Age			Positive	Mixed results or no association	Negative
Timperio et al. 2004 [103]	Australia	Cross sectional	Parks and sport fields	291 919	5-6 10-12	Walking or cycling to local destinations 3x/week	No parks nearby (10-12 year olds)	x (G, B)		
							Few sporting venues (10-12 year olds)	x (G)	x (B)	
Carver et al. 2005 [57]	Australia	Cross sectional	Sport facilities in local neighbourhood	347	12-13	Walking for exercise, walking to/from school, walking for transport, walking the dog, cycling for recreation, cycling to/from school, and cycling for transport	Parents' perception of the neighbourhood having good places for being physically active	x (G, recr cycling, walking dog) (B, transp cycling)	x (B, recr cycling, walking dog), (G, trans cycling), x (walking for exercise, transport, to school)	
Giles-Corti et al. 2002 [91]	Australia	Cross sectional	POS	1803	18-59	Walking for transport and recreation in last 2 weeks Walking as recommended (6x30 min/week)	Access to POS	x (transp, recommendations)	x (recr)	
							Access to beach	x (recr)	x (recommended)	x (transp)
Giles-Corti et al. 2005 [96]	Australia	Cross sectional	POS	1803	18-59	Walking for recreation and transportation in last 2 weeks	Accessibility of POS - >5 walking session /week (>150 min)		x	
							Accessibility of POS - >6 walking session /week (>180 min)	x		
Giles-Corti et al. 2003 [104]	Australia	Cross sectional	POS	1803	18-59	Walking for recreation and transportation in last 2 weeks, Walking as recommended (6x30 min/week)	Access to attractive POS	x (walking as recommended)		

Troped et al. 2003 [105]	USA	Cross sectional	Community walking trail	413	18+	Transportation PA: Minutes walking (to work/school/store + average/day) and minutes cycling (to work/school/store + average/day)	Distance to a community paved rail-trail			x
Wendel-Vos et al. 2004 [106]	The Netherlands	Cross sectional	Parks, woods and sportsgrounds	11541	20-59	Walking and cycling	Square area of sportsgrounds	x (cycling, comm) (walking LT+comm)	x (walking, comm) (walking LT+comm)	
							Square area of parks		x (walking, and cycling comm), (walking and cycling LT+comm),	
							Square area of woods		x (walking and cycling comm), (walking and cycling LT+comm)	

POS = Public Open Space, PA = Physical Activity, USA = Unites states of America, G = Girls, B = Boys, transp = transportation, recr = recreational, comm = commuting purposes, LT = Leisure Time

3.6. CHARACTERISTICS OF PUBLIC OPEN SPACES RELATED TO PUBLIC OPEN SPACE VISITATION AND PHYSICAL ACTIVITY

Chapter 3.5 demonstrated that there still is some inconsistency in the literature on the association between the availability and accessibility of public open spaces and physical activity. According to the conceptual model of Bedimo-Rung et al. (2005), other aspects of public open spaces could possibly explain these inconsistencies. The model of Bedimo-Rung consists of six categories of characteristics what possibly influence public open space visitation and physical activity: features, condition, access, aesthetics, safety and policies [88]. However, as physical and social characteristics were the focus of this doctoral thesis, policy related characteristics were not included in this doctoral thesis, whereas a category on social characteristics was added. Furthermore, Paquet et al. (2013) also showed that the characteristics of public open spaces, and not the number of public open spaces are related to cardio-metabolic health and physical activity in an Australian adult sample [107].

Over the last years the amount of research on this topic has grown substantially. However before the onset of this doctoral thesis, not many studies were conducted in Europe or among adolescents, whilst many studies focussed solely on parks, had small sample sizes and a qualitative design. Therefore, in the following sections, studies focussing on other populations were included but special attention was paid to studies with adolescent samples.

3.6.1. FEATURES

Qualitative studies revealed that children and adolescents prefer parks and public open spaces with a variety of features for active and sedentary activities and for structured and unstructured play [108,109], these features can be natural or man-made features.

3.6.1.1. NATURAL FEATURES

A systematic review of qualitative research has indicated that natural features such as trees (to climb in), bushes, large open fields, grass, flowers and water features may be important for children's, adolescents' and adults' public open space visitation and physical activity [110]. Furthermore, an Australian study revealed that adolescent girls perform more moderate- to vigorous-intensity physical activity after school if their closest public open space had trees that provided shade [101].

3.6.1.2. MAN MADE FEATURES

In a review of qualitative research, playgrounds were identified as positive features for physical activity and park use among children and their parents, although playgrounds are often designed for young children (< 8-years-old) [108,110], poorly equipped, or outdated [110]. However, an Australian study revealed that 8- to 9-year-old boys, but not girls, performed more moderate- to vigorous-intensity physical activity when more playgrounds were present in their neighbourhood [101]. Furthermore, a US study identified the activity settings within 45 parks that were used by adolescents and children using direct observations. The authors concluded that children used playgrounds (within the parks) most frequently, followed by a playing field. Among the few adolescents that were observed in the parks, the playground was used most often, followed by a basketball field (mostly by boys) and baseball field (mostly by boys) [111]. Furthermore, similar results were found in a study in 38 US parks, where basketball courts were the park areas with the highest number of park users among all age groups, followed by sport fields, playgrounds and greenspace. Additionally, in this study, the highest energy expenditure was observed in playgrounds, followed by basketball courts, green space and sport fields [99].

Among adults and adolescent girls, natural and constructed trails were reported to be positive features for park visitation [110]. These qualitative results were confirmed by a US study looking into the associations between park features and park-based physical activity, where a positive association was found between the presence of trails and adult physical activity [112].

3.6.1.3. SUPPORTING AMENITIES

A qualitative systematic literature review has identified supporting amenities such as barbeques, benches, drinking fountains and toilets as important characteristics for park visitation and physical activity among park users of all ages and the provision of shade as important for children and caregivers. Furthermore, dog related facilities were identified as important factors for dog owners' park visitation and physical activity [110]. Quantitative research has confirmed these results as a higher number of amenities in a park has been associated with more park users [99]. More specifically, more park users (all ages) were observed in areas with shelters, drinking fountains and benches compared to areas without these amenities whilst the presence of drinking fountains was related to higher total energy expenditure in a park area [99]. However, the presence of benches and picnic tables was associated with lower mean energy expenditure in a park area [99].

3.6.2. CONDITION

Qualitative studies indicated that the maintenance and cleanliness (presence of litter, full rubbish bins, dogs mess) of parks is important for adults, adolescents and children, as is the maintenance of playing surfaces and equipment (uneven playing surface, lack of grass) [108,110]. Vandalized facilities were identified as a discouraging feature to visit public open spaces by adolescents in a focus group study [113]. These qualitative findings are supported by an observational study from the US where more users were observed in a basketball court in good condition compared to a basketball court in poor condition. However, the same study observed more users at a poorly-maintained grass field compared to a well-maintained grass field [99].

3.6.3. AESTHETICS

In the qualitative review of McCormack et al. (2010), park aesthetics was found to be important for all age groups: graffiti and vandalism discouraged park use, wildlife was perceived both positive (e.g., positive experiences with wildlife in the park encouraged park use among Australian 6- to 18-year-old youth) and negative (e.g., fear of wildlife could discourage park use among 17- to 18-year-old adolescents in a US study) and natural aspects such as trees, bushes and fresh air were positive features for children, adolescents and adults [108,110]. However, a Scottish focus group study revealed that adolescents consider graffiti as an attractive characteristic, as long as it is located at designated spaces (e.g. graffiti wall) [113].

3.6.4. SIZE OF PUBLIC OPEN SPACES

Giles-Corti et al. (2005) reported that public open spaces should be sufficiently large because larger public open spaces tend to have more attributes and could possibly satisfy the needs of all users [96]. This is supported by the results of the observational study of Loukaitou-Sideris et al. 2010 in 100 US parks, who revealed that a larger park size was associated with larger absolute numbers of children in the parks [114].

3.6.5. SAFETY

In this section all safety-related elements of public open spaces will be discussed. Perceived safety is a very important factor for the use of public open spaces for people of all ages and related to most of the characteristics described above. For example, dangerous or poorly maintained features could possibly influence fear of injuries (features and maintenance), whereas the presence of graffiti could influence feelings of safety (aesthetics). A Scottish

qualitative study with 13- to 14-year-old adolescents revealed that overgrown dark places, poor lighting, vandalism and litter made them feel less safe and less likely to visit a public open space [113]. Additionally, in a US focus group study among 12- to 14-year-old adolescents, uneven grass, holes in the grounds and glass on the courts made sport fields unsafe and less attractive to use [115]. An Australian study revealed that adolescent girls performed more moderate- to vigorous-intensity physical activity after school if their closest public open space had signage regarding dogs [101]. Contradictory, in an observational study in the US, safety-related features in parks (e.g., park staff, lighting, emergency phones) were negatively related with the number of children in the park [114]. However, a Brazilian survey study reported overall safety, dangerous traffic and lighting not to be related to park-based physical activity among 14- to 18-year-old boys, whereas poor lighting was negatively related with park-based physical activity among girls [116].

3.6.6.SOCIAL CHARACTERISTICS

Focus groups revealed that adolescents and children perceive the presence of older youth at public open spaces as a barrier for physical activity, as they often do not let younger children play along, use bad language and bully younger children [108,113]. Additionally, the presence of drug users and people that were drinking alcohol would deter public open space visitation among adolescents [113]. The presence of peers of the same age or friends at public open spaces on the other hand was perceived as encouraging for physical activity among children and adolescents, whereas their absence would be discouraging for physical activity [108]. Additionally, adolescents indicated to go to public open spaces to have some time in quietness, away from the hassle at home or school [113].

3.6.7.CONCLUSION

The previous sections provided an overview of the existing evidence on the associations between public open space characteristics and public open space visitation and physical activity. Additionally, an overview of the existing literature at the start of the doctoral thesis can be found in Table 3. However, as most research originates from the US or Australia, the results and recommendations of these studies for public open space development may not be generalizable to European public open spaces. European cities have different city structures and differences exist concerning the physical activity- and sport-culture compared to the US and Australia. Furthermore, a review on qualitative research from 2010 on the park characteristics that influence park use and physical activity included 21 studies, of which only

five focused on adolescents. Four of these five studies had very small samples (n<20) [110]. Therefore, at the start of this doctoral thesis, additional qualitative and quantitative research was warranted to gain insight into public open space characteristics influencing adolescents' public open space visitation and physical activity.

Additionally, in order to determine causal relationships, natural experiments have to be performed. A natural experiment evaluates the effects of changes in the real world (e.g., park renovations) that are often not controlled by the researchers but by public open space administrators such as city councils and urban planners [117]. A few natural experiments showed promising results: the instalment of outdoor exercise equipment in twelve US parks was related to an increase of estimated energy expenditure among users of all ages [118] and the instalment of trails in two US cities increased physical activity levels among all ages [119,120]. Additionally, park- an playground-improvements were positively related to the number of people walking and vigorously active in an Australian park [121]. However, the improvement of two playgrounds in a New-Zealand community was related to an increase in physical activity levels among children (5- to 10-years-old) with low BMI and a decrease in physical activity among children with high BMI [122]. However, other natural experiments did not find any relation between park- an playground-improvements and physical activity among Australian 2- to 12-year-old children [123] or between the instalment of trails in a US city and time spent in physical activity among adults [124]. Additional experimental studies are needed in order to determine causal relationships of public open space characteristics with public open space visitation and physical activity. However, such natural experiments are difficult to conduct because of organisational and financial challenges [125].

Table 3: Overview of studies examining the relationship between characteristics of POS with PA

POS characteristic	Qualitative study		Quantitative study		Country	Population	Public open space	Outcome studied
	Positive association	Negative association	Positive association	Negative association				
FEATURES								
Natural features								
Trees	[110]		[101]^{G}		[101] Australia		[101] Closest POS [110] Parks	[101] MVPA after school [110] Park visitation and PA
Bushes	[110]						[110] Parks	[110] Park visitation and PA
Large open fields	[110]						[110] Parks	[110] Park visitation and PA
Grass	[110]						[110] Parks	[110] Park visitation and PA
Flowers	[110]						[110] Parks	[110] Park visitation and PA
Water features	[110]						[110] Parks	[110] Park visitation and PA
Man-made features								
Playgrounds	[110]	[108,110]	[101]^{B}, [99,111]		[101,108] Australia [99,111] USA	[99,110] All ages [101,108] Children [111] Adolescents	[101] Closest POS [108] POS [99,111] Parks	[110] Park visitation and PA [101] MVPA after school [108] Active free play [111] Number of adolescents at playground [99] Number of people at playground, energy expenditure
Basketball field			[99,111]^{B}		[99,111] USA	[99] All ages [111] Adolescents	[99,111] Parks	[111] Number of adolescents at basketball field [99] Number of people at basketball field, energy expenditure
Baseball field			[111]^{B}		[111] USA	[111] Adolescents	[111] Parks	[111] Use of baseball field
Sport fields			[99]		[99] USA	[99] All ages	[99] Parks	[99] Number of people at sport field, energy expenditure
Natural and constructed trails	[110]		[112]			[110] All ages [112] Adults	[110,112] Parks	[110] Park visitation and PA [112] PA
Supporting amenities								
BBQ	[110]					[110] All ages	[99,110] Parks	[110] Park visitation and PA
Benches/picnic tables	[110]		[99]	[99]	[99] USA	[99,110] All ages	[99,110] Parks	[110] Park visitation and PA [99] Number of park users and total energy expenditure
Drinking fountains	[110]		[99]		[99] USA	[99,110] All ages	[99,110] Parks	[110] Park visitation and PA [99] Number of park users and total energy expenditure
Toilets	[110]		[99]		[99] USA	[99,110] All ages	[99,110] Parks	[110] Park visitation and PA
Shelter (for shade or rain)	[110]		[99]			[99] All ages	[99,110] Parks	[110] Park visitation and PA [99] Number of park users
Dog related facilities	[110]					[110] All ages	[99,110] Parks	[110] Park visitation and PA
Number of supporting amenities			[99]		[99] USA	[99] All ages	[99] Parks	[99] Number of park users
CONDITION								

POS characteristic	Qualitative study		Quantitative study		Country	Population	Public open space	Outcome studied
	Positive association	Negative association	Positive association	Negative association				
Lack of cleanliness (presence of litter, full rubbish bins, dogs mess)		[108,110]			[108] Australia	[110] all ages [108] children	[110] Parks [108] POS	[110] Park visitation and PA [108] Active free play
Bad maintenance of playing surfaces and equipment		[108,110]			[108] Australia	[110] all ages [108] children	[110] Parks [108] POS	[110] Park visitation and PA [108] Active free play
Basketball court in good condition			[99]		[99] USA	[99] All ages	[99] Parks	[99] Number of park users
Grass field in Good condition				[99]	[99] USA	[99] All ages	[99] Parks	[99] Number of park users
Vandalized facilities		[113]			[113] Scotland	[113] Adolescents	[113] Parks, streets and other informal spaces (local places)	[113] POS use
AESTHETICS								
Overall aesthetics	[110]					[110] All ages	[110] Parks	
Graffiti	[113]	[110]			[113] Scotland	[110] All ages [113] Adolescents	[110] Parks [113] Parks, streets and other informal spaces (local places)	[110] Park visitation and PA [113] POS use
Evidence of vandalism		[110]				[110] All ages	[110] Parks	[110] Park visitation and PA
Wildlife	[110]	[110]				[110] All ages	[110] Parks	[110] Park visitation and PA
Trees and bushes	[108,110]				[108] Australia	[110] All ages [108] Children	[110] Parks [108] POS	[110] Park visitation and PA [108] Active free play
SAFETY								
Secluded spaces		[113]			[113] Scotland	[113] Adolescents	[113] Parks, streets and other informal spaces	[113] POS use
Poor lighting		[113]		[116][G]	[113] Scotland [116] Brazil	[113,116] Adolescents	[113] Parks, streets and other informal spaces [116] Parks	[113] POS use [116] Park-based PA
Vandalism		[113]			[113] Scotland	[113] Adolescents	[113] Parks, streets and other informal spaces (local places)	[113] POS use
Litter		[113]			[113] Scotland	[113] Adolescents	[113] Parks, streets and other informal spaces	[113] POS use
Uneven grass		[115]			[115] USA	[115] Adolescents	[115] Local parks, park field houses, school playgrounds and fields after school hours, parking lot, vacant lot	[115] POS visitation
Holes in the ground		[115]			[115] USA	[115] Adolescents	[115] Local parks, park field houses, school playgrounds and fields after school hours, parking lot, vacant lot	[115] POS visitation
Glass on the courts		[115]			[115] USA	[115] Adolescents	[115] Local parks, park field houses, school playgrounds	[115] POS visitation

POS characteristic	Qualitative study		Quantitative study		Country	Population	Public open space	Outcome studied
	Positive association	Negative association	Positive association	Negative association				
							and fields after school hours, parking lot, vacant lot	
Signage regarding dogs			[101]^{G}		[101] Australia	[101] Adolescents	[101] Closest POS	[101] MVPA after school
Safety related features (park staff, lighting, emergency phones)				[114]	[114] USA	[114] Adults and children	[114] Park	[114] Number of children in the park
Overall safety				[116]^{B}*	[116] Brazil	[116] Adolescents	[116] Park	[116] Park-based PA
Dangerous traffic				[116]^{B}*	[116] Brazil	[116] Adolescents	[116] Park	[116] Park-based PA
SIZE								
POS size			[96,114]		[96] Australia [114] USA	[96] Adults [114] Adults and children	[96] POS [114] Parks	[96] POS use [114] Number of children in the park
SOCIAL CHARACTERISTICS								
Presence of older youth		[108,113]			[108] Australia [113] Scotland	[108] Children [113] Adolescents	[108] POS [113] Parks, streets and other informal spaces	[108] Active free play [113] POS use
Presence of drug users		[113]			[113] Scotland	[113] Adolescents	[113] Parks, streets and other informal spaces	[113] POS use
Presence of peers (same age)/friends	[108]				[108] Australia	[108] Children	[108] POS	[108] Active free play
Quietness	[113]				[113] Scotland	[113] Adolescents	[113] Parks, streets and other informal spaces	[113] POS use

POS = Public Open Space, PA = Physical Activity G = Girls, B = Boys, [110] = Review article, *, no association found

4. PROBLEM ANALYSIS, OBJECTIVES AND OUTLINE OF THE THESIS

The general introduction of this doctoral thesis revealed some shortcomings in the literature concerning European physical activity prevalence data, the use of public open spaces in Europe and the characteristics associated with public open space visitation and physical activity among adolescents. Therefore, this doctoral thesis had four aims: 1) to provide an overview of current physical activity levels among European adolescents, (2) to gain insight into the use of public open spaces in Flanders, (3) to define the environmental public open space characteristics associated with adolescents' public open space visitation and physical activity and (4) to develop an experimental study using manipulated photographs to identify the most important park characteristics influencing adolescents' park visitation and physical activity.

In order to obtain health benefits, the World Health Organisation recommends adolescents to engage in at least 60 minutes of moderate- to vigorous-intensity physical activity every day [8]. It is important to get insight into the prevalence of compliance with physical activity recommendations in European adolescents. Since cultural differences and different physical activity policies exist across European countries it can be hypothesized that there will be different physical activity levels across countries. Therefore, **the first aim was to provide an overview of current adolescents' physical activity levels across European countries** (Part 2: Original Research: chapter 1).

The first study (Part 2: Original Research: chapter 1) revealed low levels of physical activity among youth across Europe, with only 6% of the Flemish girls and 17% of the Flemish boys reporting to comply to the physical activity guidelines of 60 minutes physical activity daily [126]. Public open spaces (e.g., parks, squares, playgrounds, vacant lots) are present in almost all neighbourhoods and have been shown to be an important location for adolescents' physical activity in the US [88]. However, not much is known about the use of public open spaces in Europe or Belgium and cultural and environmental differences between the US and Europe make it hard to generalize the results from US studies. Therefore, **the second aim of this doctoral thesis was to gain insight into the use of public open spaces in Flanders** (Part 2: Original Research: chapter 2). First, a study using direct observation was conducted to investigate the use of parks in Ghent (a small sized city in Flanders, Belgium that comprises an

area of 156.18 km² and 253,266 inhabitants: population density: 1622 inh/km²) [127,128]) (Part 2: Original Research: chapter 2.1). Within this study the characteristics of park users, the activity levels of park users and the types of activities performed were described. Additionally, the associations between park areas, weekday or weekend and time of day, and the observed number of park users and physical activity levels of park users for males and females and children/adolescents and adults/seniors was examined. Both children/adolescents and adults/seniors were included in this study as different age groups might use parks differently and parks should be designed to fit all age groups' needs. Furthermore, including all age groups enables the comparison of how adolescents use parks, with park use by other age groups.

Research studying the use of public open spaces among adolescents is scarce and most research originates from the US and Australia. Additionally, most existing research used measures of the neighbourhood or the public open space closest to home, assuming that these are the public open spaces most used, whereas in few studies GPS and accelerometers are used to objectively define location-specific physical activity. Furthermore, it has been shown that individual differences exist concerning the use of public open spaces (e.g., gender and age differences). Consequently, there was a need for European studies using GPS devices and accelerometers to define location specific public open space use and physical activity among adolescents. Therefore, a second study was performed to describe the prevalence, frequency and context (i.e., company, locations and reason) of public open space visitation and to gain insight into the individual, social and physical environmental factors associated with time, sedentary time and physical activity at public open spaces among Flemish (Belgian) adolescents by using GPS devices and accelerometers (Part 2: Original Research: chapter 2.2).

Previous research has shown that specific aspects of public open spaces such as quality, safety, aesthetics and features of public open spaces may be more important than the availability and accessibility of public open spaces [88]. However, at the start of this doctoral thesis, research concerning the association of public open space characteristics with public open space visitation and physical activity among adolescents and in Europe was scarce. Therefore, **the third aim of this doctoral thesis was to define the environmental public open space characteristics associated with adolescent public open space visitation and physical activity** (Part 2: Original Research: chapter 3).

Given the rapid growth in research studying the associations between public open space characteristics and public open space visitation or physical activity since the beginning of this doctoral thesis, it was needed to provide an overview of the current knowledge on the specific characteristics that are associated with adolescents' public open space visitation and physical activity. Therefore, a systematic literature review on the characteristics of public open spaces associated with public open space visitation and physical activity was performed. The aim of this reviews was to provide a comprehensive overview of the existing qualitative and quantitative evidence on public open space characteristics associated with public open space visitation and physical activity among adolescents (Part 2: Original Research: chapter 3.1).

Second, a study using walk-along interviews (i.e. an interview that takes place while walking in the public open space that is the subject of the interview) was conducted to identify the physical and social environmental factors influencing adolescents' public open space visitation and physical activity (Part 2: Original Research: chapter 3.2).

In the general introduction, the need for experimental studies was emphasized. Natural experiments can inform policies about which public open space characteristics are causally related to adolescents' physical activity. Additionally, policy makers and urban planners are often limited by budgets, which forces them to prioritize on the most important specific characteristics of public open spaces that are related to public open space visitation and physical activity among adolescents. Therefore, in 2014 it was attempted to perform a natural experiment in a park in Ghent (Flanders, Belgium) that was planned to be renovated in 2015. However, due to changes in the planning, the renovations have not been executed up to today (2017). Subsequently, it was not possible to continue the natural experiment. However, the baseline data have been used to gain insight in to the current use of parks in Flanders (Belgium) (see second aim and Part 2: Original Research: chapter 2.1). An alternative and cost-effective method to examine which park characteristics are most important to attract adolescents to visit and be physically active in parks is the use of manipulated photographs (i.e. where virtual environmental changes are examined without actual changing the real park environment) [129-131]. Using manipulated digital photographs allows to systematically vary specific park characteristics and control other characteristics such as the weather. Responses to colour digital photographs have shown good validity in relation to on-site responses [132-

134] and can offer a good alternative to natural experiments. Based on the above described walk-along study (Part 2: Original Research: chapter 3) public open space characteristics (including parks) that are important for adolescent public open space visitation and physical activity were identified. However, to gain insight into which public open space characteristics are most important, experimental research was needed. Therefore, **the fourth aim of this doctoral thesis was to develop an experimental study using manipulated photographs to identify the most important park characteristics influencing adolescents' park visitation and physical activity** (Part 2: Original Research: chapter 4). In order to fulfil this aim, a study using a digital questionnaire including manipulated photographs was conducted (Part 2: Original Research: chapter 4.1).

5. OVERVIEW OF METHODS AND STUDIES

In total, seven papers are included in this doctoral thesis: four research articles that report the results of four cross-sectional studies and three systematic literature reviews. A wide range of methods has been used to fulfil the aims of this doctoral thesis: three systematic literature reviews, a qualitative study using interviews, an observational study, a study using GPS devices and accelerometers and an experimental study using manipulated photographs.

The first aim of this doctoral thesis was to gain insight into the prevalence of adolescents' physical activity levels in European countries. This systematic literature review was part of a European project called DEDIPAC: "DEterminants of DIet and Physical ACtivity". In 2013 twelve European member states established this knowledge hub through a joint programming initiative. One of DEDIPAC's aims was to enable a better standardized and more continuous pan-European needs analysis, i.e. to monitor dietary, physical activity and sedentary behaviours and changes in these behaviours across the life course and within populations to identify target populations for (policy) interventions [135]. The first step within this project was to perform a systematic literature review with the aim to provide an overview of the existing studies that monitor cross-European levels of physical activity among youth, to describe the variation in population levels of physical activity in youth and to define challenges regarding the assessment and reporting methods.

The second aim of this doctoral thesis was to gain insight into the use of public open spaces in Flanders. Two studies were conducted to achieve this aim. The first study (Part 2: Original Research: chapter 2.1) used direct observations to gain insight into the characteristics of park users, activity levels of park users, type of activities that were performed and the associations of park areas, day and time of day with the observed number of park users and physical activity levels of park users. The study was conducted in two parks in Ghent: "Park de Vijvers" (51,313m² , including a pond, grassy field with playground, wooded areas, trails) and "Paul Van Tieghempark" (31,502m², including a pond, grassy field with playground, wooded areas and trails). The Environmental Assessment of Public Recreation Spaces (EAPRS) tool was used to provide a descriptive overview of the park amenities and features of the two parks that were included in this study. EAPRS provides an all-inclusive assessment of the physical environment of a park with high reliability [136]. The System for Observing Play and Recreations in Communities (SOPARC) was used to obtain direct information on park use and

characteristics of the park users. SOPARC has been shown to be a reliable and feasible instrument to assess physical activity in parks and individual characteristics (e.g., age and gender) of park users [137]. Before the observations, both parks were divided into observable target areas (five to seven areas per park) which represented specific locations within the parks (e.g., wooded area, grassy area with a playground, ponds, trails). On-site observations were conducted for nine days (simultaneous measurements in the two parks), by trained researchers, who scanned each target area and recorded the age, gender, ethnicity and activity level of the park users. Associations of the independent variables (park area and temporal characteristics: week or weekend day, time of the day) with the dependent variables (number of park users and physical activity levels) were examined using multilevel Hurdle models using the package LME4 in R version 3.1.0.

The second study within chapter 2, used GPS and accelerometer data in order to describe the prevalence, frequency and context (i.e., company, locations and reason) of public open space visitation and to gain insight into the individual, social and physical environmental factors associated with time, sedentary time and physical activity at public open spaces among adolescents. First participants were asked to fill in a questionnaire concerning demographics. Next, participants were instructed to wear a GPS device and accelerometer for four to five days, after which the GPS data were used to create a personal map of all locations visited during these days. These maps were used during a one-on-one interview where participants were asked about the reasons for visiting, the activities performed and company at public open spaces. All GPS and accelerometer data were processed and matched using the Personal Activity and Location Movement System (PALMS©). Within PALMS all data points were allocated to one of the four domains: transport, home, school or leisure and data from the one-on-one interviews were added. Multilevel Hurdle and Gamma models were used to account for the structure of the data, skewness and high amount of zero's.

The third aim was to gain insight into the public open space characteristics related to public open space visitation and physical activity. A systematic literature review was conducted with the aim to gain insight into the public open space characteristics associated with public open space visitation and physical activity. In April 2017 four literature databases were searched for peer reviewed articles, focussing on 12- to 16-year-old adolescents, written in English, published after the first of January 2000 and examining associations of public open space

characteristics with public open space visitation and physical activity. The search resulted in seventeen qualitative studies and fourteen quantitative studies.

Additionally, a qualitative study was conducted using walk-along interviews with 30 12- to 16-year-old adolescents. A walk-along interview is conducted while walking within the public open space and allows to study participants' interpretation of the public open space while experiencing it and thus uses the advantages of both face-to-face interviews and observations. Adolescents were recruited by face-to-face contact in low SES neighbourhoods. The interview consisted of three consecutive parts which were audiotaped. The first component of the interview included questions that assessed demographics, use of public open space, sport club membership and frequency of attending sport club. Second, questions assessing the social environment were asked. These open-ended questions were used to prompt a conversation about the social environment and to gain more insight and in-depth information on how the social context, modelling, social networks and social trust and cohesion influenced public open space visitation and physical activity. Third, a semi-structured walk-along interview was conducted in the public open space where participants were recruited. The participant and researcher walked through the public open space while conducting the walk-along interview. Qualitative data from the audiotaped walk-along interviews and the social environmental questions were transcribed verbatim and analysed using Nvivo 10 software. Data analysis was guided by a grounded theory approach, which consists of systematic, yet flexible, guidelines for collecting and analysing qualitative data to construct theories from the data [138].

The fourth aim of this doctoral thesis was to develop an experimental study using manipulated photographs to identify the most important park characteristics influencing adolescents' park visitation and physical activity. A choice-based conjoint (CBC) study using manipulated photographs was conducted in ten secondary schools in Ghent. CBC analyse makes it possible to examine how people value different characteristics (e.g., park upkeep) of a product (e.g., a park) and to understand which characteristics are the most influential on participants' preferences. Furthermore, within CBC analysis it is possible to systematically vary specific park characteristics (which is often not possible in park renewal projects) and control other environmental characteristics (such as the weather) [139]. First, 6912 photographs were developed and manipulated on ten characteristics with multiple levels using Photoshop

software. A web-based questionnaire was developed using Sawtooth software (Lighthouse studio 9.2.0). In the first section of the questionnaire, participants were asked to complete items concerning demographics, school, residence, highest level of parental education, nationality, ethnicity, park use and physical activity levels. In the second part of the questionnaire, participants were asked to perform two sets of CBC tasks, each with ten individual choice tasks. Participants were presented with two photographs of a park with different combinations of levels of park characteristics. In the first set of tasks, participants had to choose which park from the two displayed parks they preferred to visit, while in the second task, they were asked to choose the park most supportive for physical activity. Hierarchical Bayes Estimations were used to calculate (1) average utilities that represent the desirability of each level within a park characteristic and (2) importance scores which reflect the effect each park characteristic had on the choice.

Table 4: Overview of methods and studies

Study	Study aims	Study design	Methods
Aim 1: Provide an overview of current adolescent physical activity levels across European countries.			
Chapter 1.1	Provide an overview of the existing literature on physical activity in youth, describe the variation in population levels of physical activity in European youth and the assessment methods used to assess physical activity, and to define challenges regarding the assessment and reporting methods.	– Systematic literature review – Six literature databases: PubMed, EMBASE, CINAHL, PsychINFO, SportDiscus and OpenGrey – N = 30 studies included – Search conducted in June 2014 and updated in February 2016	– Systematic literature review – Search terms for 'physical activity' OR 'sedentary behaviour' AND 'Europe' AND 'Countries'/'multi-country'/'international' – All articles were screened on title by one researcher, and on abstract and full text by two researchers – Data extraction and quality assessment was performed by two researchers
Aim 2: Gain insight into the use of public open spaces in Flanders			
Chapter 2.1	Gain insight into the characteristics of park users, activity levels of park users and type of activities that were performed. Gain insight into the associations between park areas, day and time of day and the observed number of park users and physical activity levels of park users.	– Cross sectional observational study – Two parks in Ghent (Flanders, Belgium) were selected in consultation with the green space administrators from the city of Ghent – Data collection: July-October 2014 – N = 837 park users	– Systematic observations using SOPARC – Two parks in Ghent (Belgium) – Seven days of simultaneous observations, four times / day (7:30, 12:30, 15:30, 18:30). – Multilevel Hurdle models were used to examine associations between park area and temporal characteristics (week or weekend day, time of the day) and the observed number of park users and physical activity levels of park users
Chapter 2.2	Describe the prevalence, frequency and context (i.e., company, locations and reason) of public open space visitation and gain insight into the individual, social and physical environmental factors associated with time, sedentary time and physical activity at public open spaces among adolescents.	– Cross sectional study – Purposive sampling of six schools in Ghent, all students from randomly selected classes (1st-4th grade) were asked to participate – Data collection: September – December 2015 – N = 173 participant with valid data	– GPS data, accelerometer data and one-on-one interviews – PALMS was used to merge and process all accelerometer and GPS data – Hurdle and gamma models were used to examine associations between individual and social environmental variables and time, sedentary time and physical activity at public open spaces

Study	Study aims	Study design	Methods
Aim 3: Identify public open space characteristics associated with public open space visitation and physical activity			
Chapter 3.1	Gain insight into the associations of specific physical characteristics of outdoor public open spaces with public open space visitation and physical activity among adolescents.	– Systematic literature review – Four literature databases: Sportdiscus, MEDLINE, Web of Science and Leisure Tourism Abstracts. – Qualitative studies ○ N = 17 articles included – Quantitative studies ○ N = 14 articles included – Search conducted in April 2017	– Systematic literature review – Search terms were used for 'adolescents' AND 'physical activity' OR 'public open space visitation' AND 'public open spaces' – All articles were screened on title, abstract and full text by two researchers – Data extraction and quality assessment were conducted by two researchers
Chapter 3.2	Identify the physical and social environmental factors associated with adolescents' public open space visitation and physical activity.	– Qualitative walk-along interviews – Convenience sampling at public open spaces of 12- to 16-year-old adolescents in Ghent, Brussels and Antwerp (Belgium) – Data collection: July-October 2014 – N = 30	– Participants were interviewed while walking in public open spaces – Interviews were transcribed verbatim – Analyses was guided using a grounded theory approach – Nvivo 10 software
Aim 4: Identity critical environmental park characteristics related to adolescent park visitation and physical activity			
Chapter 4.1	To examine the relative importance of specific park characteristics on park visitation and park-based physical activity among adolescents	– Cross-sectional online survey – Experiment with manipulated photographs – Ten schools were willing to participate. All students from randomly selected classes (1^{st}-4^{th} grade) were asked to participate – Data collection: September-November 2016 – N = 972	– Online questionnaire with two integrated sets of CBC tasks. – CBC analyse – Photographs of parks manipulated in ten characteristics – Hierarchical Bayes estimations to examine main effects

6. PUBLICATIONS INCLUDED IN THE THESIS

CHAPTER 1

Linde Van Hecke, Anne Loyen, Maïté Verloigne, Hidde P. van der Ploeg, Jeroen Lakerveld, Johannes Brug, Ilse De Bourdeaudhuij, Ulf Ekelund, Alan Donnelly, Ingrid Hendriksen, Benedicte Deforche on behalf of the DEDIPAC consortium. Variation in population levels of physical activity in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC. International Journal of Behavioral Nutrition and Physical Activity, Vol. 13, No. 1, 2016, p. 70.

CHAPTER 2

Linde Van Hecke, Jelle Van Cauwenberg, Peter Clarys, Delfien Van Dyck, Jenny Veitch, Benedicte Deforche. Active Use of Parks in Flanders (Belgium): An Exploratory Observational Study. International Journal of Environmental Research and Public Health, Vol 14, No. 1, 2017, p. 30-35.

Linde Van Hecke, Hannah Verhoeven, Peter Clarys, Delfien Van Dyck, Nico Vandeweghe, Tim Baert, Benedicte Deforche, Jelle Van Cauwenberg. Factors related with public open space use among adolescents: a study using GPS devices and accelerometers. International Journal of Health Geographics, Vol 17. No. 3, 2018

CHAPTER 3

Linde Van Hecke, Ariane Ghekiere, Jenny Veitch, Jelle Van Cauwenberg, Peter Clarys, Delfien Van Dyck, Benedicte Deforche. Public open space characteristics influencing adolescents' use and physical activity: a systematic literature review of qualitative and quantitative studies. Under review in Health and Place

Linde Van Hecke, Benedicte Deforche, Delfien Van Dyck, Ilse De Bourdeaudhuij, Jenny Veitch, Jelle Van Cauwenberg. Social and Physical Environmental Factors Influencing Adolescents' Physical Activity in Urban Public Open Spaces: A Qualitative Study Using Walk-Along Interviews. In: PLoS ONE, Vol. 11, No. 5, 2016.

CHAPTER 4

Linde Van Hecke, Ariane Ghekiere, Jelle Van Cauwenberg, Jenny Veitch, Ilse De Bourdeaudhuij, Delfien Van Dyck, Peter Clarys, Nico Van de Weghe, Benedicte Deforche. Park characteristics preferred for adolescent park visitation and physical activity: a choice-based conjoint analysis using Manipulated photographs. Under review in Landscape and Urban Planning

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PART 2: ORIGINAL RESEARCH

CHAPTER 1

PHYSICAL ACTIVITY LEVELS AMONG EUROPEAN ADOLESCENTS

CHAPTER 1.1.

VARIATION IN POPULATION LEVELS OF PHYSICAL ACTIVITY IN EUROPEAN CHILDREN AND ADOLESCENTS ACCORDING TO CROSS-EUROPEAN STUDIES: A SYSTEMATIC LITERATURE REVIEW WITHIN DEDIPAC

Linde Van Hecke, Anne Loyen, Maïté Verloigne, Hidde P. van der Ploeg, Jeroen Lakerveld, Johannes Brug, Ilse De Bourdeaudhuij, Ulf Ekelund, Alan Donnelly, Ingrid Hendriksen, Benedicte Deforche on behalf of the DEDIPAC consortium

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REVIEW Open Access

Variation in population levels of physical activity in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC

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Abstract

Background: Regular physical activity is associated with physical, social and mental health benefits, whilst insufficient physical activity is associated with several negative health outcomes (e.g. metabolic problems). Population monitoring of physical activity is important to gain insight into prevalence of compliance to physical activity recommendations, groups at risk and changes in physical activity patterns. This review aims to provide an overview of all existing studies that measure physical activity in youth, in cross-European studies, to describe the variation in population levels of physical activity and to describe and define challenges regarding assessment methods that are used.

Methods: A systematic search was performed on six databases (PubMed, EMBASE, CINAHL, PsycINFO, SportDiscus and OpenGrey), supplemental forward- and backward tracking was done and authors' and experts' literature databases were searched to identify relevant articles. Journal articles or reports that reported levels of physical activity in the general population of youth from cross-European studies were included. Data were reviewed, extracted and assessed by two researchers, with disagreements being resolved by a third researcher. The review protocol of this review is published under registration number CRD42014010684 in the PROSPERO database.

Results: The search resulted in 9756 identified records of which 30 articles were included in the current review. This review revealed large differences between countries in prevalence of compliance to physical activity recommendations (i.e. 60 min of daily moderate- to vigorous-intensity physical activity (MVPA)) measured subjectively (5–47 %) and accelerometer measured minutes of MVPA (23–200 min). Overall boys and children were more active than girls and adolescents. Different measurement methods (subjective $n = 12$, objective $n = 18$) and reported outcome variables ($n = 17$) were used in the included articles. Different accelerometer intensity thresholds used to define MVPA resulted in substantial differences in MVPA between studies conducted in the same countries when assessed objectively.

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Conclusions: Reported levels of physical activity and prevalence of compliance to physical activity recommendations in youth showed large variation across European countries. This may reflect true variation in physical activity as well as variation in assessment methods and reported outcome variables. Standardization across Europe, of methods to assess physical activity in youth and reported outcome variables is warranted, preferably moving towards a pan-European surveillance system combining objective and self-report methods.

Key words: Youth, Prevalence, Assessment method, Childhood, Health behaviour, Activity level

Background

Recommendations published by the World Health Organization (WHO) state that children and adolescents should accumulate at least 60 min of moderate- to vigorous-intensity physical activity (MVPA) daily. Additionally, within these 60 min, vigorous-intensity physical activity (VPA) should be incorporated at least three times per week [1]. Such levels of physical activity are associated with physical, social and mental health benefits [2–4]. Besides, physical activity in childhood and adolescence is positively related to adult physical activity [4, 5] and health [4, 6].

To establish accurate prevalence data and to monitor changes in physical activity in youth, valid and reliable measures are required [7, 8]. Physical activity can either be measured objectively or subjectively. Traditionally, physical activity is assessed by means of self-report questionnaires, especially in larger population studies [9, 10]. Because such self-report measures are prone to bias, recently more objective assessment methods (e.g. pedometers or accelerometers) are also being used [11]. However, such objective methods come with their own challenges. For example, consensus still has to be reached regarding the accuracy of steps recorded by different pedometers [12], as well as the specific accelerometer intensity thresholds [11, 13] that correspond with low intensity physical activity (LPA), MVPA or VPA in youth. Furthermore, pedometer and accelerometer assessments do not provide information regarding the context of physical activity [14].

In 2013, twelve European Member States established a Knowledge Hub on DEterminants of DIet and Physical ACtivity (DEDIPAC) through a joint Programming Initiative. One of DEDIPAC's aims is: "enabling a better standardised and more continuous pan-European 'needs analysis', i.e. to monitor dietary, physical activity and sedentary behaviours and changes in these behaviours across the life course and within populations to identify targets and target populations for (policy) interventions" [15].

Providing an overview of the existing cross-European (i.e. more than one European country involved) studies that monitor physical activity and sedentary behaviour levels, and their reported population levels, was identified as the first step towards standardisation in population surveillance. In 2010 the WHO [16] published an extensive report, with an overview of existing national and international studies on physical activity levels in European countries. Unfortunately, this report did not provide country specific physical activity levels. Also, it was concluded that national studies used various methods and often non-standardized instruments which led to non-comparable data. Therefore, this systematic review gives an update of cross-European surveillance systems, and reports physical activity levels per country in order to enable comparison of physical activity levels between countries.

Within DEDIPAC, four systematic literature reviews have been conjointly performed to study the variation in population levels of 1) physical activity in youth (the current review) 2) sedentary behaviour in youth [17], 3) physical activity in adults [18] and 4) sedentary behaviour in adults [19]. The purpose of this systematic review is to provide an overview of existing cross-European studies on physical activity in European youth (<18 years), to describe the variation in population levels of physical activity in European youth and in assessment methods used to assess physical activity in cross-European studies, and to define challenges regarding the assessment and reporting methods. These results will be discussed in relation to possible harmonization of physical activity measurement and monitoring across Europe.

Methods

As described in the introduction this systematic literature review is part of a set of four reviews. Because the four systematic reviews originate from the same project, have similar objectives (although for different behaviours and/or age groups) and share their methodology, the introduction-, methods- and discussion sections of the review articles have obvious similarities. The search, article selection, data extraction and quality assessment were conducted conjointly for all four reviews. Subsequently, the included articles were allocated to the appropriate review. One article could be included in multiple reviews. If an article included both youth (<18 years) and adults (≥18 years) and presented stratified results, those stratified results were used in the appropriate review. If the article did not present stratified

results, the article was allocated to the most appropriate review, based on the mean age (and age distribution) of the study sample. Before the search commenced, review protocols were written based on the "Centre for Reviews and Dissemination's guidance for undertaking reviews in health care" [20], and registered in the PROSPERO database [21]. The review protocol of this review on physical activity in youth is published under registration number CRD42014010684. The reporting of this systematic review adheres to the preferred reporting items of the PRISMA-P checklist (Additional file 1).

Search strategy

The search was conducted in June 2014 and updated in February 2016. Six databases (PubMed, EMBASE, CINAHL, PsycINFO, SportDiscus and OpenGrey) were searched using similar search strategies, adapted to each database. The following search terms were used: 'Physical activity' OR 'Sedentary behaviour' AND 'Europe' (including all individual country names) AND 'Countries'/'Multi-country'/'International'. Both the index terms and the title and abstract were searched and synonyms (e.g. for physical activity: physically active and physical exercise) were used. The complete search string can be found in Additional file 2. Based on the in- and exclusion criteria described below, search filters of the databases were used when possible, for example to select the appropriate publication period or language.

In addition, complementary search strategies were used. After the full-text review phase, the reference lists of the included articles were scanned (backward tracking) and a citation search was performed for the included articles (forward tracking) to identify potentially appropriate articles. Also, several experts in the field of physical activity and sedentary behaviour were contacted to provide additional articles. Finally, all authors involved in the four reviews were asked to search their own literature databases for appropriate articles. All additionally retrieved articles underwent the same selection process as the original articles - as described below.

Article selection

All retrieved records were imported into Reference Manager 12 (Thomson Reuters, New York). Duplicates were hand-searched and removed. Records were included if they were journal articles, reports or doctoral dissertations (further referred to as 'articles') written in English. To be included articles needed to report on observational studies conducted after 01-01-2000 (to avoid reporting outdated data) in the general, healthy population. In addition, articles were only included if they provided data for two or more European countries (as defined by the Council of Europe) [22]. With regard to physical activity, articles were included if they reported total physical activity (e.g. minutes/day or meeting recommendations), and/or physical activity in leisure time. Articles that only reported on transport, occupational or household physical activity were excluded. Both subjective (e.g. questionnaires) and objective (e.g. accelerometers) measures were included.

Three researchers (AL,LVH,MV) were involved in the article selection, data extraction and quality assessment. For the title selection, the three researchers each independently reviewed 1/3 of the titles of the retrieved articles. For the abstract and the full-text selection, data extraction and quality assessment, the three researchers each covered 2/3 of the articles, so that each article was independently reviewed, extracted and assessed by two different researchers. Disagreement between the two researchers was resolved by the third researcher.

Data extraction

A standardized data extraction file was used to extract data regarding the study characteristics, the study sample, the assessment methods, the reported outcomes, and the findings. We did not obtain the original data. The complete data extraction file can be found in Additional file 3. To present the data more clearly and to allow for comparisons between age groups, the results are presented and discussed separately for children (age 0–12) and adolescents (age 13–18). When a study reported on a sample that covered both childhood and adolescence (e.g. 9–15 year olds), the data was presented in both sections in this manuscript.

Quality assessment

A quality score was used to provide a general overview of the quality of the included articles. The 'Standard quality assessment criteria for evaluating primary research papers from a variety of fields' [23] was used for the assessment. The checklist consists of fourteen items to be scored 'Yes' (2 points), 'Partial' (1 point), 'No' (0 points) and 'Not applicable'. The summary score was calculated as follows: Total sum ((number of 'Yes' x 2) + (number of 'Partial' x 1))/Total possible sum (28 – (number of 'Not applicable' x 2)). This instrument was chosen because it provides the opportunity to assess and compare the quality of different study designs, focuses on both the research and the reporting, and allows researchers to indicate that an item is not applicable, without affecting the total quality score. The complete quality assessment file can be found in Additional file 4.

Results

Overview of the existing cross-European studies on physical activity in youth

Our search (original and update combined) resulted in 9756 articles, after exclusion of duplicates. After

the titles and abstracts were screened, 581 full texts were obtained and reviewed. This resulted in 80 articles, of which 30 articles reported data on physical activity in youth [24–53]. The three main reasons for exclusion for the four reviews together were: (a) fewer than two countries involved ($n = 183$), (b) outcome not reported per country ($n = 144$), and (c) suitability of the reported outcome variables, for example when only active transportation was reported ($n = 135$) (Fig. 1).

We only included articles published between 2000 and 2016 but 80 % ($n = 24$) were published after 2008. All articles except two had a cross-sectional design: Ortega et al. [37] used a longitudinal design, but only follow up data of this study were included in the review, because baseline data were collected before 2000 and Ekelund et al. [47] pooled data from cross-sectional and longitudinal studies. The number of European countries included in these articles, ranged from 2 to 36. All articles included data from boys and girls and sample size ranged from 301 to 479,674 participants. The quality score ranged from 0.68 to 1 (maximum score = 1). A short summary of the articles including demographic characteristics of the sample, assessment methods and reported outcome variables per article is presented in Table 1.

Variation in population levels of physical activity in European Youth

Levels of physical activity are presented by European country for children (0–12 years) in Table 2 and for adolescents (13–18 years) in Table 3. Most articles included in this review provided data from datasets of larger European studies such as the ENERGY-, EPAPA-, EYHS, HBSC-, ICAD-, IDEFICS, ISCOLE- or TOYBOX-study. To describe the variation in population levels of physical activity in youth (Tables 2 and 3; Figs. 2 and 3), not all articles were included to avoid presenting results from the same data twice. If there was more than one article per study reporting exactly the same outcome variable in a similar way in the same sample, the article with the largest amount of information was chosen [28–30, 32, 38, 39, 42, 44, 46, 47, 49, 50]. No data were available for the following countries: Andorra, Azerbaijan, Bosnia and Herzegovina, Cyprus (no data for adolescents), Georgia, Liechtenstein, Monaco, Montenegro, San Marino and Serbia. These countries ($n = 10$) represent 21 % of the 47 European countries but less than 3 % of the European population [54]. For clarity, values presented in the tables are for the total sample numbers, except where the articles reported data for boys and girls separately. For the Health Behaviour in School Children (HBSC study), the most recent data was presented in the tables

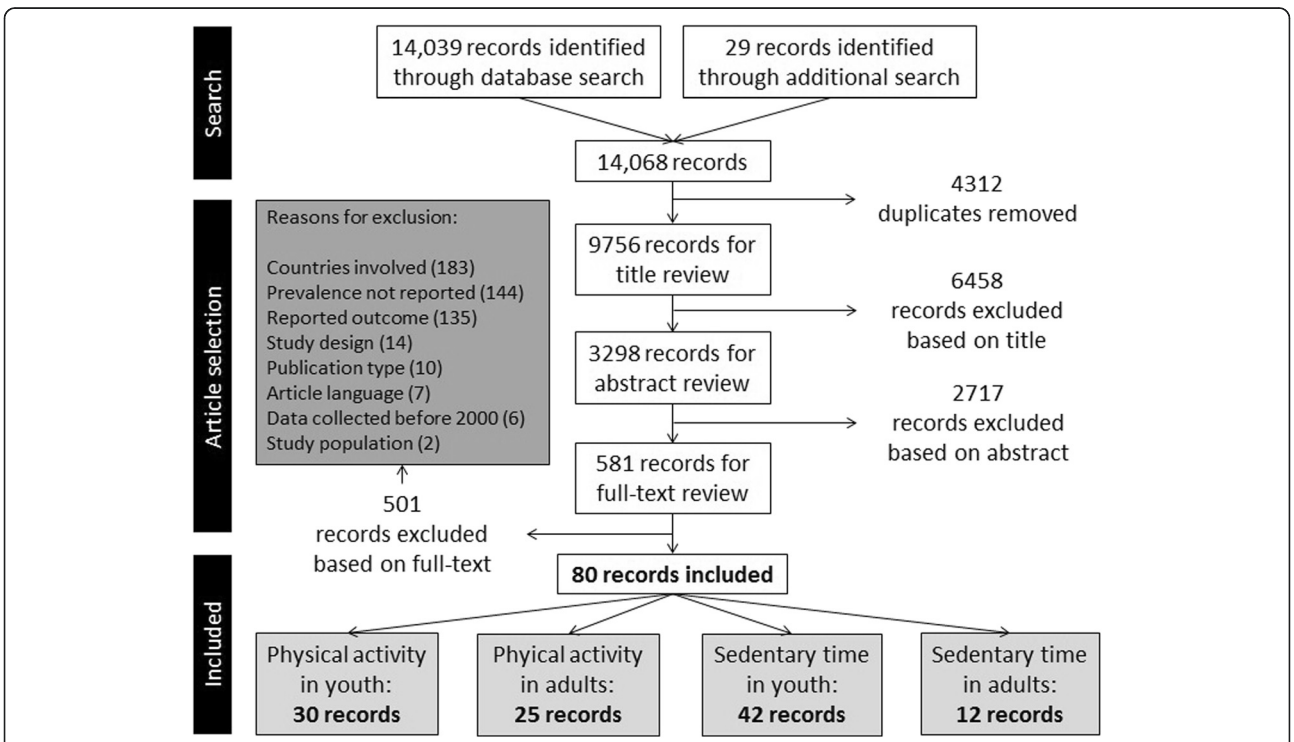

Fig. 1 Flowchart of the combined review process

Table 1 Study information and sample characteristics of the articles included in the systematic review

Article	Study	Study design	Quality score (0–1)	Number of European countries	Number of European participants	Demographics				Physical activity assessment method	Reported physical activity outcome variables
						Age range	Gender, Female	SES	Weight status		
Biddle et al. (2009) [24]	/	CS	0.91	3	623	13–18	60 %	32–63 % Low SES[a]	n. r.	E.M.A.	Total physical activity (min/day)
Duncan et al. (2015) [25]	/	CS	0.96	2	2 760	9–14	55 %	n. r.	Mean BMI: 18.1 km/m^2	Pedometer	Average steps/day
Ramirez-Rico et al. (2014) [26]	/	CS	0.86	2	367	10–14	61 %	n. r.	BMI range[a]: 19.0–21.0 kg/m^2	Accelerometer	MPA (min/day, 2296–4012 CPM) VPA (min/day, >4012 CPM) MVPA (min/day, >2296 CPM)
Soos et al. (2014) [27]	/	CS	0.86	4	700	12–18	57 %	n. r.	n. r.	E.M.A.	% meeting recommendations MVPA (≥60 min MVPA on 7 days/week)
Fernandez-Alvira et al. (2013) [28]	ENERGY	CS	0.95	7	5 284	10–12	54 %	33 % Low PEL	Overweight: 20.4 %	Questionnaire	Total physical activity (min/day)
Jimenez-Pavon et al. (2012) [29]	ENERGY	CS	0.86	7	7 213	10–12	52 %	22–63 % Low PEL[a]	Mean BMI: 19.1 kg/m^2	Questionnaire	% meeting recommendations MVPA (≥60 min MVPA on 7 days/week)
Verloigne et al. (2012) [30]	ENERGY	CS	0.95	5	687	10–12	53 %	n. r.	Mean BMI: 19.0 kg/m^2	Accelerometer	Total physical activity (cnts/15 s/day) MVPA (min/day, >3000 CPM) % meeting recommendations MVPA (≥60 min MVPA on 7 days/week)
Yildirim et al. (2014) [31]	ENERGY	CS	0.95	5	722	10–12	53 %	n. r.	n. r.	Accelerometer	Total physical activity (cnts/15 s/day) MVPA (min/day, >3000 CPM)
Aibar et al. (2013) [32]	EPAPA	CS	0.95	2	301	Mean: 14.45	53 %	Range FAS score[a]: 2.62-2.82 (max score = 3)	BMI range[a]: 19.2–21.2 kg/m^2	Accelerometer	MVPA (min/day, >2292 CPM) 10 min bouts of MVPA (min/day) % meeting recommendations MVPA (≥60 min MVPA on 7 days/week) % of participants meeting guidelines 10 min bouts
Aibar et al. (2014) [33]	EPAPA	CS	0.82	2	829	Mean: 14.33	55 %	Range FAS score[a]: 6.52–7.08 (max score = 9)	BMI range[a]: 18.9–20.2 kg/m^2	Accelerometer	MVPA (min/day, >2292 CPM)
Andersen et al. (2006) [34]	EYHS	CS	0.91	3	1 732	9 and 15	53 %	n. r.	BMI range[a]: 16.4–21.8 kg/m^2	Accelerometer	Total physical activity (CPM/day)
Ekelund et al. (2004) [35]	EYHS	CS	1.00	4	1 292	9–10	51 %	n. r.	Overweight: 14.8 %	Accelerometer	Total physical activity (CPM/day) LPA (% of total time, 500–2000 CPM) MVPA (% of total time, > 2000 CPM) VPA (% of total time, > 3000 CPM)

Table 1 Study information and sample characteristics of the articles included in the systematic review *(Continued)*

Nilsson et al. (2009) [36]	EYHS	CS	1.00	4	1 184	9 and 15	50 %	n. r.	n. r.	Accelerometer	Total physical activity (CPM/day) MVPA (min/day, >2000 CPM)
Ortega et al. (2013) [37]	EYHS	LT, CH	0.91	2	503	15 and 18	54 %	UEM[a]: 27.6–33.7 %	BMI range[a]: 16.4–17.3 kg/m^2	Accelerometer	MVPA (min/day, >2000 CPM)
Riddoch et al. (2004) [38]	EYHS	CS	0.86	4	2 185	9 and 15	n. r.	n. r.	n. r.	Accelerometer	Total physical activity (CPM/day) MVPA (min/day, >1000 CPM for 9 year olds, >1500 CPM for 15 year olds)
Janssen et al. (2005) [39]	HBSC 01/02	CS	0.95	27	128 845	10–16	47–53 % [a]	n. r.	Overweight[a]: 5.1–25.4 %	Questionnaire	% meeting recommendations (≥60 min MVPA on ≥5 days)
HBSC Report 2004 [40]	HBSC 01/02	CS	0.73	27	162 306	11, 13 and 15	51 %	27.6 % Low SES	Overweight[a]: 7.9–12 %	Questionnaire	% meeting recommendations (≥60 min MVPA on ≥5 days) Mean number of days with physical activity ≥1 h
Haug et al. (2009) [41]	HBSC 05/06	CS	1.00	34	204 534	11, 13 and 15	49 %	n. r.	Overweight[a]: 7.6–28.8 %	Questionnaire	% meeting recommendations (≥60 min MVPA on ≥5 days) % of participants VPA ≥2 h/week
HBSC Report 2008 [42]	HBSC 05/06	CS	0.68	34	188 147	11, 13 and 15	51 %	n. r.	Overweight[a]: 10–17 %	Questionnaire	% meeting recommendations (≥60 min MVPA on 7 days) % of participants VPA ≥2 h/week
Ramos et al. (2013) [43]	HBSC 09/10	CS	0.82	2	9 444	11, 13 and 15	54 %	n. r.	Overweight: 13–16.9 %	Questionnaire	% meeting recommendations (≥60 min MVPA on ≥5 days) % of participants VPA ≥2 times/week
HBSC Report 2012 [44]	HBSC 09/10	CS	0.68	34	178 531	11, 13 and 15	51 %	2–42 %[a] Low SES (FAS =1)	Overweight[a]: 10–18 %	Questionnaire	% meeting recommendations (≥60 min MVPA on 7 days) % of participants VPA ≥2 h/week
Kalman et al. (2015) [45]	HBSC 01/02, 05/06, 09/10	CS	0.91	26	479 674	11, 13 and 15	51 %	n. r.	n. r.	Questionnaire	% meeting recommendations (≥60 min MVPA on 7 days)
HBSC report 2016 [46]	HBSC 13/14	CS	0.86	36	199 316	11, 13 and 15	51 %	Mean FAS score[a]: 38–76	Overweight[a]: 11–19 %	Questionnaire	% meeting recommendations (≥60 min MVPA on 7 days) % of participants VPA ≥2 h/week
Ekelund et al. (2012) [47]	ICAD	Pooled data (CS and LT)	0.91	7	15 614	4–18	52 %	n. r.	Overweight: 25 %	Accelerometer	Total physical activity (CPM/day) MVPA (min/day, >3000 CPM)
Hildebrand et al. (2015) [48]	ICAD	Pooled data (CS and LT)	0.91	6	10 367	6–18	53 %	n. r.	Overweight: 16 %, Obese: 5 %	Accelerometer	Total physical activity (CPM/day) MVPA (min/day, >3000 CPM)
Gwozdz et al. (2013) [49]	IDEFICS	CS	0.73	8	4 425	2–9	n. r.	Education mother (ISCED): 4	n. r.	Accelerometer	MVPA (% of total time, > 1680 CPM)
Konstabel et al. (2014) [50]	IDEFICS	CS	0.96	8	7 684	2–11	50 %	n. r.	n. r.	Accelerometer	% meeting recommendations (≥60 min MVPA on 7 days)

Table 1 Study information and sample characteristics of the articles included in the systematic review *(Continued)*

Kovacs et al. (2015) [51]	IDEFICS	CS	0.96	8	16 228	2–9	49 %	% with low mother education (ISCED): 11 %	n. r.	Accelerometer	% meeting recommendations (≥60 min MVPA on 7 days)
Katzmarzyk et al. (2015) [52]	ISCOLE	CS	0.96	3	1 664	9–11	55 %	n. r.	BMI range[a]: 17.7–19.5	Accelerometer	MVPA (min/day, >2296 CPM) VPA (min/day, > 4012 CPM)
De Craemer et al. (2015) [53]	TOYBOX	CS	0.96	6	4 045	3–6	48 %	n. r.	n. r.	Accelerometer and pedometer	Average steps/day % meeting recommendations (≥180 min MVPA on 7 days)

PEL Parental education level, *FAS* Family affluence scale max score =100), *UEM* University Education Mother, *ISCED* International Standard Classification of Education (Range value 1–6), *SES* Socio-economic status, *BMI* Body mass index, *CS* cross-sectional, *LT* longitudinal, *CH* cohort, *E.M.A.*, Ecological momentary assessment, *n. r.* not reported, *LPA* light-intensity physical activity, *MPA* moderate-intensity physical activity, *MVPA* moderate- to vigorous-intensity physical activity, *VPA* vigorous-intensity physical activity, *ENERGY* European energy balance research to prevent excessive weight gain among youth; *EPAPA* Evaluation and promotion of adolescent physical activity, *EYHS* European youth heart study, *HBSC* Health behaviour in school-aged children, *ICAD* International children's accelerometry database, *IDEFICS* Identification and prevention of dietary and lifestyle induced health effects in children and infants, *ISCOLE* The international study of childhood obesity, lifestyle and the environment

[a]These publications only presented stratified demographics, the numbers shown here represent the range

Table 2 Levels of physical activity in children (0–12 years) across European countries. This table displays a summary of the results reported in the articles included in the systematic review

Country	Total physical activity (CPM/day)	Average steps/ day (Pedometer)	MVPA (min/day)		MVPA (% of total time) (Accelerometer)	% meeting guidelines of 60 min MVPA daily			% vigorously active ≥2 h/week
			Accelerometer	Questionnaire		Accelerometer	Pedometer	Questionnaire	
Albania								38(B) 31(G) [46]	24 [46]
Armenia								29(B) 20(G) [46]	31 [46]
Austria								33(B) 26(G) [46]	67 [46]
Belgium	636(B) 484(G) [30]	16799(B) 13488(G) [25]	42(B) 23(G) [30]	37(B) 37(G) (FL) [28]	11^{ft} 9^{pt} 11^{n} (FL) [49]	14(B) 2(G) [30]	60 [25]	16(B) 13(G) (FL) [29]	71 (FL) [46]
		11318° 9095* [53][a]				34(B) 12(B) [50]		21(B) 14(G) (FL) [46]	61 (WAL) [46]
						40° 21* [53][a]		29(B) 16(G) (WAL) [46]	
Bulgaria		9777° 9426* [53]					30° 30* [53][b]	42(B) 30(G) [46]	44 [46]
Croatia								39(B) 26(G) [46]	39 [46]
Cyprus					8^{ft} 8^{pt} 8^{n} [49]	20(B) 2(G) [50]			
Czech Republic								29(B) 23(G) [46]	41 [46]
Denmark	740(B) 600(G) [38]		183(B) 142(G) [38]					19(B) 11(G) [46]	68 [46]
	738 [47][a] 581 [47][b]		36 [47][a] 30 [47][b]						
Estonia	788(B) 661(G) [38]		200(B) 169(G) [38]		11^{ft} 10^{pt} 11^{n} [49]	27(B) 13(G) [50]		21(B) 15(G) [46]	43 [46]
	625 [47][b]		38 [47][b]						
Finland			71 [52]					47(B) 34(G) [46]	68 [46]
France								25(B) 11(G) [46]	54 [46]
Germany		11507° 9966* [53]			9^{ft} 10^{pt} 9^{n} [49]	33(B) 14(G) [50]	50° 31* [53][b]	25(B) 16(G) [46]	62 [46]
Greece	560(B) 424(G) [30]	9656° 8667* [53]	41(B) 25(G) [30]	33(B) 26(G) [28]		10(B) 0(G) [30]	27° 20* [53][b]	11(B) 6(G) [29]	58 [46]
								20(B) 11(G) [46]	
Hungary	580(B) 556(G) [30]		41(B) 37(G) [30]	46(B) 39(G) [28]	0^{ft} 0^{pt} 0^{n} [49]	14(B) 2(G) [30]		35(B) 22(G) [29]	45 [46]
						21(B) 9(G) [50]		34(B) 24(G) [46]	
Iceland								31(B) 22(G) [46]	48 [46]
Ireland								45(B) 31(G) [46]	52 [46]
Italy					8^{ft} 8^{pt} 8^{n} [49]	10(B) 3(G) [50]		17(B) 8(G) [46]	47 [46]
Latvia								25(B) 18(G) [46]	43 [46]
Lithuania								27(B) 20(G) [46]	42 [46]
Luxembourg								34(B) 21(G) [46]	72 [46]
Malta								28(B) 21(G) [46]	43 [46]

Table 2 Levels of physical activity in children (0–12 years) across European countries. This table displays a summary of the results reported in the articles included in the systematic review *(Continued)*

Republic of Moldova								35(B) 29(G) [46]	31 [46]
Netherlands	528(B) 492(G) [30]		40(B) 26(G) [30]	41(B) 35(G) [28]		16(B) 2(G) [30]		24(B) 12(G) [29]	82 [46]
			26ŧ [31]					24(B) 15(G) [46]	
Norway	868(B) 740(G) [38]		193(B) 171(G) [38]	57(B) 50(G) [28]				46(B) 35(G) [29]	69 [46]
	711 [47][b]		45 [47][b]					32(B) 19(G) [46]	
Poland		11230° 10880* [53]					43° 42* [53][b]	34(B) 27(G) [46]	49 [46]
Portugal	747(B) 613(G) [38]		194(B) 163(G) [38]					26(B) 16(G) [46]	35 [46]
	562 [47][b]		29 [47][b]						
			56 [52]						
Romania								39(B) 23(G) [46]	41 [46]
Russian federation								26(B) 18(G) [46]	35 [46]
Slovak republic								37(B) 26(G) [46]	51 [46]
Slovenia				48(B) 42(G) [28]				34(B) 27(G) [29]	49 [46]
								27(B) 18(G) [46]	
Spain		12669° 10438* [53]	51° 32* [26]	44(B) 30(G) [28]	11^{ft} 11^{22pt} 11^{n} [49]	30(B) 12(G) [50]	61° 37* [53][b]	25(B) 9(G) [29]	48 [46]
								39(B) 28(G) [46]	
Sweden					12^{ft} 12^{pt} 11^{n} [49]	34(B) 15(G) [50]		21(B) 13(G) [46]	59 [46]
Switzerland	656(B) 580(G) [30]		50(B) 43(G) [30]			28(B) 13(G) [30]		26(B) 17(G) [46]	72 [46]
	647 [47][g] 702 [47][h]		44 [47][g] 22 [47][h]						
FYRM								36(B) 30(G) [46]	35 [46]
Turkey								27(B) 19(G) [44]	32 [44]
Ukraine								33(B) 28(G) [46]	34 [46]
United Kingdom	756 (SC) [47][c] 597 [47][d] 570 [47][e] 602 [47][f]	12637(B) 11782(G) [25]	26 (SC) [47][c] 35 [47][d] 29 [47][e] 28 [47][f]				37 [25]	25(B) 20(G) (ENG) [46]	45 (ENG) [46]
			49° 37* (ENG) [26]					29(B) 21(G) (SC) [46]	63 (SC) [46]
			63 [52]					26(B) 15(G) (WAL) [46]	44 (WAL) [46]

Values are the mean unless stated otherwise; Average day unless stated otherwise; ŧ = Median; ° = weekday; * = weekend; *min* minutes, *CPM* counts per minute, *MVPA* moderate- to vigorous-intensity physical activity, *FYRM* The former Yugoslav republic of Macedonia, *B* Boys, *G* Girls, *ENG* England, *SC*, Scotland, *WAL* Wales, *FL* Flanders, *WR* Walloon region; Ekelund et al. [47] reported data from pooled studies: [47] [a] = CSCIS (Copenhagen school child intervention study); [47] [b] = Riddoch; [47] [c] = MAGIC (= Movement and activity Glasgow intervention in children); [47] [d] = ALSPAC (= Avon longitudinal Study of Parents and Children); [47] [e] = PEACH (= Personal and Environmental Associations with Children's Health); [47] [f] = SPEEDY (= Sport, Physical activity and eating behaviour, environmental determinants in young people); [47] [g] = KISS (Kinder sportstudie); [47] [h] = Ballabeina; [53] [a] In this study pedometers were used except in Belgium accelerometers were used; [53] [b] Guidelines for pre-schoolers were used: 180 min MVPA/day; Verloigne et al. [30] reported counts per 15 s, to harmonize results, this was multiplied by four to obtain counts per minute; Gwozdz et al. [49] reported measures separately for full-time employed mother (=ft); part-time employed mother (=pt) and non-employed mother (=n)

Table 3 Levels of physical activity in adolescents (13–18 years) across European countries. This table displays a summary of the results reported in the articles included in the systematic review

Country	Total physical activity (CPM/day)	Average steps/day (Pedometer)	MVPA (min/day)		% meeting guidelines of 60 min MVPA daily				% vigorously active on ≥2 h/week
			Accelerometer	E.M.A	Accelerometer	Pedometer	E.M.A	Questionnaire	
Albania								29(B) 14(G) [46]	30 [46]
Austria								18(B) 5(G) [46]	62 [46]
Armenia								25(B) 14(G) [46]	34 [46]
Belgium		16799(B) 13488(G) [25]				60 [25]		17(B) 6(G) (FL) [46]	69 (FL) [46]
								17(B) 11(G) (WR) [46]	60 (WR) [46]
Bulgaria								25(B) 18(G) [46]	42 [46]
Croatia								25(B) 12(G) [46]	43 [46]
Czech Republic								20(B) 13(G) [46]	52 [46]
Denmark	520(B) 452(G) [38]		77(B) 60(G) [38]					16(B) 7(G) [46]	76 [46]
	581 [47][b]		30 [47][b]						
Estonia	679(B) 497(G) [38]		110(B) 74(G) [38]					18(B) 9(G) [46]	52 [46]
	625 [47][b]		38 [47][b]						
Finland			71 [52]					22(B) 13(G) [46]	68 [46]
France			43; 48[°] 28[*] 17[BTS] 18[°BTS] 12[*BTS] [32]		17; 2[BTS] [32]			14(B) 6(G) [46]	51 [46]
Germany								16(B) 9(G) [46]	64 [46]
Greece								15(B) 7(G) [46]	50 [46]
Hungary				39(B)[°] 40(G)[°] 48(B)[*] 41(G)[*] [24]			21(B) 20(G) [27]	24(B) 11(G) [46]	49 [46]
Iceland								25(B) 14(G) [46]	21 [46]
Ireland								25(B) 9(G) [46]	53 [46]
Italy								11(B) 5(G) [46]	52 [46]
Latvia								21(B) 14(G) [46]	52 [46]
Lithuania								23(B) 12(G) [46]	59 [46]
Luxembourg								26(B) 9(G) [46]	65 [46]
Malta								16(B) 9(G) [46]	35 [46]
Republic of Moldova								25(B) 22(G) [46]	36 [46]
Netherlands								22(B) 12(G) [46]	74 [46]
Norway	654(B) 553(G) [38]		92(B) 82(G) [38]					23(B) 8(G) [46]	74 [46]
Poland								25(B) 11(G) [46]	42 [46]

Table 3 Levels of physical activity in adolescents (13–18 years) across European countries. This table displays a summary of the results reported in the articles included in the systematic review *(Continued)*

Portugal	635(B) 483(G) [38]		110(B) 80(G) [38]				18(B) 5(G) [46]	40 [46]
	562 [47][b]		29 [47][b]					
			56 [52]					
Romania				53(B)$^{\circ}$ 58(G)$^{\circ}$ 66(B)* 74(G)$^{\circ}$ [24]		36 (B) 48(G) [27]	21(B) 11(G) [46]	37 [46]
Russian federation							21(B) 11(G) [46]	44 [46]
Slovak republic				61(B)$^{\circ}$ 45(G)$^{\circ}$ 69(B)$^{\circ *}$ 36(G)$^{\circ}$ [24]		44(B) 26(G) [27]	25(B) 13(G) [46]	47 [46]
Slovenia							21(B) 7(G) [46]	48 [46]
Spain			68; 72° 55* 41^{BTS} 43$^{BTS\circ}$ 32^{BTS*} [32]		60; 19^{BTS} [32]		28(B) 12(G) [46]	55 [46]
Sweden							15(B) 10(G) [46]	62 [46]
Switzerland	647 [47][g]		44 [47][g]				12(B) 7(G) [46]	68 [46]
FYRM							27(B) 12(G) [46]	37 [46]
Turkey							18(B) 9(G) [44]	31[44]
Ukraine							26(B) 16(G) [46]	40 [46]
United Kingdom	597 [47][d,] 570 [47][e]	12637(B) 11782 (G) [25]	35 [47][d] 29 [47][e]		37 [25]	53(B) 40(G) [27]	18(B) 9(G) (ENG) [46]	51 (ENG) [46]
			63 [52]				14(B) 11(G) (SC) [46]	58 (SC) [46]
							16(B) 8(G) (WAL) [46]	50 (WAL) [46]

Values are the mean unless stated otherwise; Average day unless stated otherwise; ○ = weekday;*= weekend; min = minutes; *MVPA* moderate- to vigorous-intensity physical activity, *E.M.A.* Ecological momentary assessment, *FYRM* The former Yugoslav republic of Macedonia, *B* Boys, *G* Girls, *ENG* England, *SC* Scotland, *WAL* Wales, *FL* Flanders, *WR* Walloon region; Ekelund et al. [47] reported data from pooled studies: [47][b] = Riddoch; [47][d] = ALSPAC (= Avon longitudinal study of parents and children); [47] [e] = PEACH (= Personal and environmental associations with children's health); [47] [g] = KISS (Kinder Sportstudie); Aibar et al. [32] reported MVPA separately for 10 min bouts (=BTS)

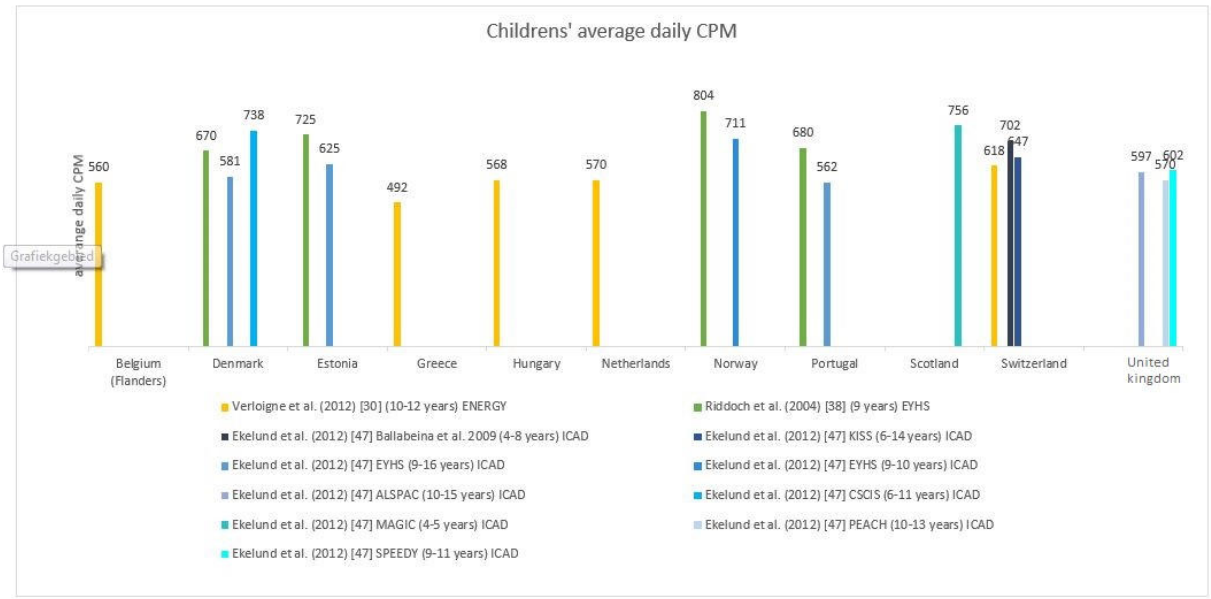

Fig. 2 Average daily counts per minute in children across countries based on different articles. When data were reported separately for boys and girls [30, 38], the mean was reported. Ekelund et al. [47] reported on pooled data from different studies and cleaned and processed the data together. In the Figure the original study is mentioned in the legend: ENERGY = European energy balance research to prevent excessive weight gain among youth; EYHS = European Youth Heart Study; ICAD = International Children's Accelerometry Database; CSCIS = Copenhagen School Child Intervention Study; ALSPAC = Avon Longitudinal Study of Parents and Children; PEACH = Personal and Environmental Associations with Children's Health; SPEEDY = Sport, Physical activity and Eating behaviour, Environmental Determinants in Young People; MAGIC = Movement and Activity Glasgow Intervention in Children; KISS = Kindersportstudie; Verloigne et al. [30] reported counts per 15 s, to harmonize results, this was multiplied by four to obtain counts per minute

(survey13/14). The values of the 11 year olds were included in Table 2 and the values for the 15 year olds in Table 3.

Generally, boys were more active than girls independent of the measurement method or reported outcome variables, and children tended to be more active than adolescents (Tables 2 and 3). Moreover, in most European countries, less than 50% of children and adolescents complied with the recommended levels of physical activity, regardless of the measurement method. However, there was a large variation between countries. The HBSC study was arguably the best option to compare PA levels in youth between European countries, because it included data from 36 countries. Self-reported data from HBSC 2016 [46] indicated that among 11-year-olds Italy (13 %), Denmark (15 %) and Greece (16 %) had the lowest prevalence of children meeting recommended physical activity levels, while Finland (41 %), Ireland (38 %) and Bulgaria (36 %) had the highest prevalence. However, self-report data are likely to provide less valid data of compliance to physical activity recommendations [55].

Comparison of physical activity levels among youth in European countries using objective measurement methods

For effective comparison of physical activity levels among youth between articles, the same physical activity outcome variables have to be reported and data have to be cleaned and processed the same way. The best comparable outcome reported in the included articles (i.e. not influenced by the specific intensity thresholds that are used), was accelerometer measured average daily counts per minute (CPM). In Figs. 2 and 3, accelerometer derived average daily CPM are presented for children and adolescents. Average daily counts per minute varied between 492 CPM and 804 CPM for children and between 486 and 647 CPM for adolescents. Some differences between countries can be observed for the data in children, for example within one study [38] an average CPM of 804 was reported for Norway compared with an average CPM of 670 for Denmark. Furthermore, some variation within countries can be observed, for example one study [47] reported an average CPM of 711 for 9–10 year old Norwegians, whereas another study [38] reported an average CPM of 804 for Norwegian 9-year-olds. In adolescents more similar results between and within countries were found.

The objectively measured outcome that was reported most frequently was "minutes of MVPA per day". Figure 4 shows minutes of MVPA per day in children for articles reporting accelerometer derived data. Different intensity thresholds for converting accelerometer-based CPM to minutes per day of MVPA were used across the articles.

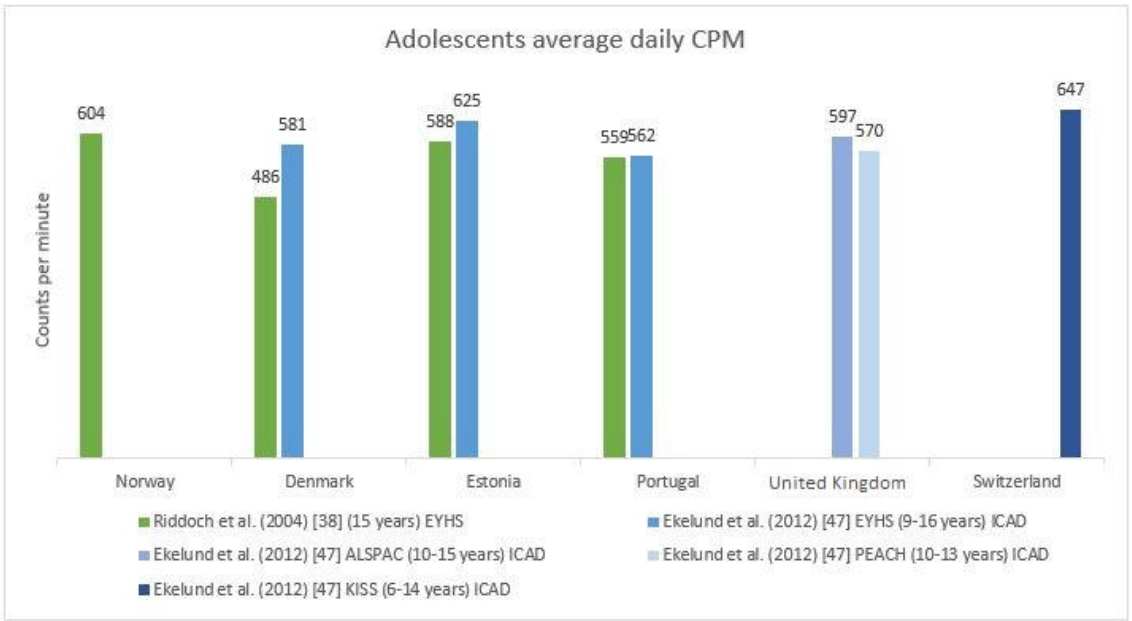

Fig. 3 Average daily counts per minute in adolescents across countries based on different articles. When data were reported separately for boys and girls [37, 38], the mean was reported. Ekelund et al. [47] reported on pooled data from different studies and cleaned and processed the data together. In the Figure the original study is mentioned in the legend: EYHS = European Youth Heart Study; ICAD = International Children's Accelerometry Database; ALSPAC = Avon Longitudinal Study of Parents and Children; PEACH = Personal and Environmental Associations with Children's Health; KISS = Kindersportstudie

These cut-off decisions resulted in different classifications of activity levels. For example Riddoch et al. [38] reported 179 min of MVPA in children per day in Portugal, compared to 29 min reported by Ekelund et al. [47]. This resulted in a difference of 150 min of MVPA per day in the same country, even though these articles used the same dataset from the EYHS study. The high values of MVPA across any country reported in the articles of Riddoch et al. [38] and Nilsson et al. [36] can be attributed to the low intensity thresholds that were used to define MVPA (respectively >1000 CPM and >2000 CPM) compared to the intensity threshold used in the other articles [30, 31, 47] (>3000 CPM).

Figure 5 shows minutes of MVPA per day in adolescents for articles reporting accelerometer derived data. The same pattern can be observed as in children. Minutes of MVPA per day in the articles of Riddoch et al. [38] and Nilsson et al. [36] were markedly higher in each country than the values reported in the article of Ekelund et al. [47] due to the intensity thresholds that were used (respectively >1000 CPM and >2000 CPM and >3000 CPM). However, Ortega et al. [37] and Nilsson et al. [36] used the same intensity threshold (>2000 CPM) but did not report similar levels of MVPA due to differences in age of participants and period of data collection: participants in the article of Nilsson et al. [36] were 15 years old compared to 18 years in the article of Ortega et al. [37] and data used by Nilsson et al. [36] was collected between 1997 and 2000 and the data reported by Ortega et al. [37] was collected in 2007. This indicates that variation in levels of physical activity reported in different articles is not only due to the intensity thresholds that were used, but also to sample characteristics and data collection periods.

Comparison of physical activity levels among youth in European countries using subjective measurement methods

In Fig. 6 subjectively measured percentage of children meeting the guidelines is presented for 5 countries. ENERGY data reported by Jimenez-Pavon et al. [29] and data from the most recent HBSC report 2016 [46] (survey 09/10) are compared. Data from both studies included about 50 % girls and age groups were comparable (11 year olds [44] and 10–12 years olds [29]). The HBSC study [46] included one single item question on the number of days over the 'past' week that participants were physically active for a total of at least 60 min per day. This included sport participation, active transportation, physical activity at school and physical activity at home. The ENERGY study [29] on the other hand included questions on sports participation (2 questions) and active transport (4 questions) in a 'usual' week. The two studies reported

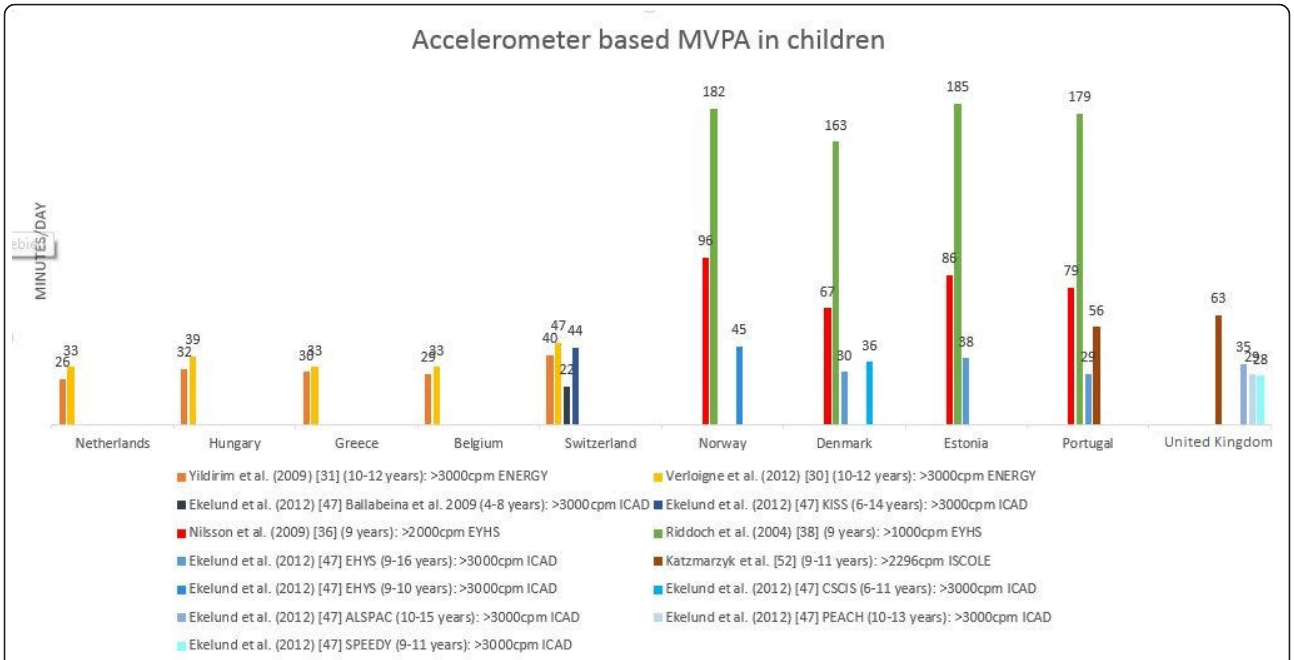

Fig. 4 Minutes per day of accelerometer based MVPA in children across countries based on different articles. When data were reported separately for boys and girls [30, 38] or week and weekend day [36], the mean was reported. Ekelund et al. [47] reported on pooled data from different studies and cleaned and processed the data together. In the Figure the original study is mentioned in the legend. ENERGY = European energy balance research to prevent excessive weight gain among youth, EYHS = European Youth Heart Study; ICAD = International Children's Accelerometry Database; CSCIS = Copenhagen School Child Intervention Study; ALSPAC = Avon Longitudinal Study of Parents and Children; PEACH = Personal and Environmental Associations with Children's Health, SPEEDY = Sport, Physical activity and Eating behaviour, Environmental Determinants in Young People, KISS = Kindersportstudie; ISCOLE = The international study of childhood obesity, lifestyle and the environment

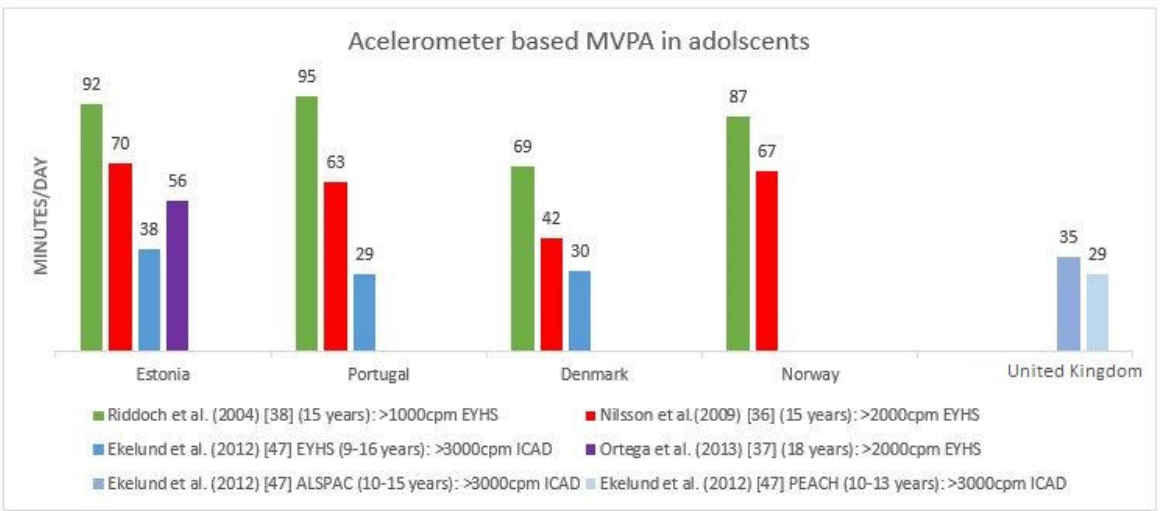

Fig. 5 Minutes per day of accelerometer based MVPA in adolescents across countries based on different articles. When data were reported separately for boys and girls [37, 38] or week and weekend day [36], the mean was reported. Ekelund et al. [47] reported on pooled data from different studies and cleaned and processed the data together. In the Figure the original study is mentioned in the legend. EYHS = European Youth Heart Study; ICAD = International Children's Accelerometry Database; ALSPAC = Avon Longitudinal Study of Parents and Children; PEACH = Personal and Environmental Associations with Children's Health

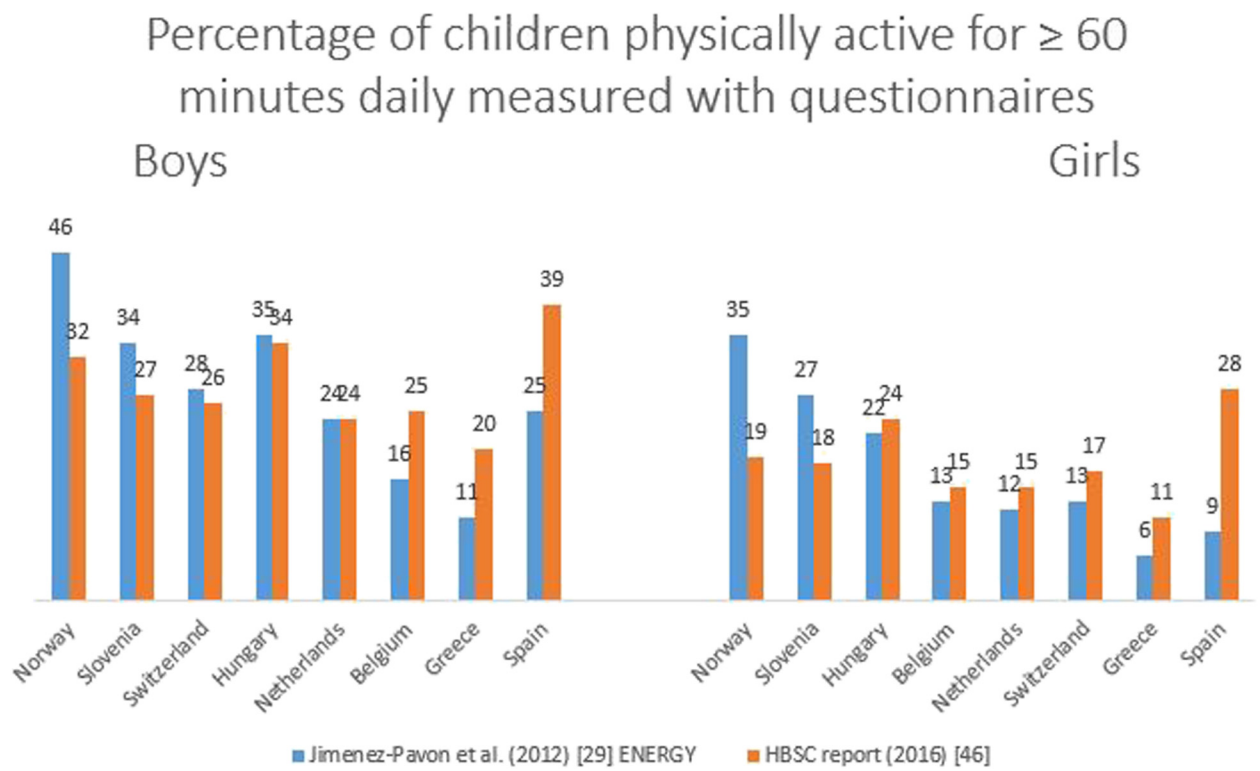

Fig. 6 Questionnaire based percentage of boys and girls engaging in MVPA for ≥ 60 min daily in 8 countries across Europe. ENERGY = European energy balance research to prevent excessive weight gain among youth; HBSC = health behaviour in school-aged children

different amounts of children meeting the guidelines of 60 min of daily MVPA within each European country. For Spain, Greece, Belgium, Hungary (only girls), The Netherlands (only girls) and Switzerland (only girls) the HBSC study [46] reports higher percentages of compliance to physical activity guidelines compared to the ENERGY study [29], whereas for Norway, Slovenia, Switzerland (only boys) and Hungary (only boys) the ENERGY study [29] reports higher percentages of children meeting guidelines compared to the HBSC study [46].

Variation in assessment methods and reported outcome variables

Because there was a large variation in measurement methods and reported outcome variables, an overview is presented in Table 4. Measurement of physical activity was done either objectively (with accelerometers) or subjectively (e.g. with questionnaires or ecological momentary assessment). More than half ($n = 16$) of the articles included in this review used accelerometers, two used pedometers, ten articles used a questionnaire and two articles used ecological momentary assessment. All questionnaires were self-administered. Eight articles asked questions regarding physical activity in the seven days prior to questionnaire administration and two asked questions regarding an "average week". The outcomes were reported in seventeen different ways (for example one article [35] reported "% of total time spent in MVPA", whereas another [37] reported "MVPA in minutes per day"). Of these reported outcomes "% meeting the guidelines on physical activity" ($n = 15$) and "minutes per day of MVPA" (both measured objectively and subjectively) ($n = 11$) were used most often. Five different intensity thresholds were used to define MVPA measured with accelerometers in children ranging from >1000 CPM to >3000 CPM and four different intensity thresholds were used in adolescents ranging from >1500 CPM to >2296 CPM. Several accelerometer models were used in the included articles: the EYHS study [34–38] used an older ActiGraph model (MTI7164), whereas in the EPAPA study [32, 33], study by Ramirez-Rico et al. [26] and ISCOLE study [52] more recent ActiGraph models were used (GT1M and GTX3). In the ENERGY study [30, 31], IDEFICS study [49–51] and ICAD study [47, 48] a combination of different models was used: the ENERGY-study used one old (Actitrainer) and two new (GT1M, GT3X) ActiGraph models, the IDEFICS-study used one old (Actitrainer) and one newer ActiGraph model (GT1M) and the ICAD-study pooled studies that used three different models (two older models: 7164, 71256 and one newer model: GT1M).

Table 4 Assessment methods and reported outcome variables in the articles included in the systematic review

Study	N	Article number reference list
Not part of an international study	4	[24–27]
ENERGY	4	[28–31]
EPAPA	2	[32, 33]
EYHS	5	[34–38]
HBSC	8	[39–46]
ICAD	2	[47, 48]
IDEFICS	3	[49–51]
ISCOLE	1	[52]
TOYBOX	1	[53]
Assessment method		
Accelerometer	16	[26], ENERGY [30, 31], EPAPA [32, 33], EYHS [34–38], ICAD [47, 48], IDEFICS [49–51], ISCOLE [52]
Pedometer	2	[25], TOYBOX [53]
Questionnaire	10	ENERGY [28, 29], HBSC [39–46]
Ecological momentary assessment	2	[24, 27]
Accelerometer model		
ActiGraph		
GT1M	8	[26], ENERGY [30, 31], IDEFICS [49–51], ICAD [47, 48]
GT3X	5	ENERGY [30, 31], EPAPA [32, 33], ISCOLE [52]
Actitrainer	5	ENERGY [30, 31], IDEFICS [49–51]
7164	7	EYHS [34–38], ICAD [47, 48]
71256	2	ICAD [47, 48]
Pedometer model		
Yamax Digiwalker SW-200	1	[25]
Omron Walking Style Pro pedometers (HJ-720IT-E2)	1	TOYBOX [53]
Name of questionnaire		
ENERGY questionnaire	2	ENERGY [28, 29]
HBSC questionnaire (Prochaska et al. (2001) [67])	8	HBSC [39–46]
Mode of questionnaire administration		
Self-administered	10	ENERGY [28, 29], HBSC [39–46]
Timing physical activity measurement		
Average per week	2	ENERGY [28, 29]
Last seven days/week	8	HBSC [39–46]
Reported outcome variables		
Total physical activity	12	[24, 25], ENERGY [28, 30, 31], EYHS [34–36, 38], ICAD [47, 48], TOYBOX [53]
Accelerometer measured (cnts/min/day)	6	EYHS [34–36, 38], ICAD [47, 48]
Accelerometer measured (cnts/15 s/day)	2	ENERGY [30, 31]
Steps/day	2	[25], TOYBOX [53]
Self-report diary/questionnaire (min/day)	2	[24], ENERGY [28]
MVPA (min/day)	11	[26], ENERGY [30, 31], EPAPA [32, 33], EYHS [36–38], ICAD [47, 48], ISCOLE [52]
MPA (min/day)	1	[26]
VPA (min/day)	2	[26], ISCOLE [52]
% of total time LPA/MVPA/VPA	2	EYHS [35], IDEFICS [49]

Table 4 Assessment methods and reported outcome variables in the articles included in the systematic review *(Continued)*

LPA (500–2000 CPM)	1	EYHS [35]
MVPA (>1680 CPM)	1	IDEFICS [49]
MVPA (>2000 CPM)	1	EYHS [35]
VPA (>3000)	1	EYHS [35]
% of participants meeting recommendations	15	[27], ENERGY [29, 30], EPAPA [32], HBSC [39–46], IDEFICS [50, 51], TOYBOX [53]
≥ 60 min on ≥ 5 days	4	HBSC [39–41, 43]
≥ 60 min on ≥ 7 days	10	[27], ENERGY [29, 30], EPAPA [32] HBSC [42, 44–46], IDEFICS [50, 51],
≥ 180 min on ≥ 7 days	1	TOYBOX [53]
physical activity accumulated in 10 min bouts ≥ 60 min on ≥ 7 days	1	EPAPA [32]
% of participants ≥ 2 days/week VPA	5	HBSC [41–44, 46]
Mean number of days active ≥ 1 h	1	HBSC [40]
10 min bouts MVPA(min/day)	1	EPAPA [32]
Intensity thresholds used for:		
MVPA children (0–12 years old)		
> 1000 CPM	1	EYHS [38]
> 1680 CPM	1	IDEFICS [49]
> 2000 CPM	4	EYHS [34–37]
> 2296 CPM	4	[26], IDEFICS [50, 51], ISCOLE [52]
> 3000 CPM	4	ENERGY [30, 31], ICAD [47, 48]
MVPA adolescents (13–18 years old)		
> 1500 CPM	1	EYHS [38]
> 2000 CPM	3	EYHS [34, 36, 37]
> 2296 CPM	4	[26], EPAPA [32, 33], ISCOLE [52]
> 3000 CPM	2	ICAD [47, 48]
Guidelines mentioned in article		
≥60 min physical activity on at ≥5 days	4	HBSC [39–41, 43]
≥60 min of physical activity at ≥7 days	18	[26, 27], ENERGY [29, 30], EPAPA [32, 33], EYHS [34–36, 38], HBSC [42, 44–46], ICAD [47], IDEFICS [50, 51], ISCOLE [52]
≥180 min of physical activity at ≥7 days	1	TOYBOX [53]
No guidelines reported	7	[24, 25], ENERGY [28, 31], EHYS [37], IDEFICS [49], ICAD [48]
Results reported separately for		
Study (article pooled multiple studies)	3	ICAD [47, 48], HBSC [45]
Gender	19	[24, 25, 27], ENERGY [28–30], EPAPA [32], EYHS [34–38], HBSC [40–44, 46], IDEFICS [50]
Week and weekend day	6	[24], [26], EYHS [36, 37], EPAPA [32], TOYBOX [53]
Age group	9	EYHS [34, 36–38], HBSC [40, 42, 44, 46], IDEFICS [51]
Weight status	1	IDEFICS [51]
School time/non-school time/after school time	1	[26]
Full time employed/part time-employed/non employed	1	IDEFICS [49]
School-travel-time/school time/non-school-time/ weekend-night-time/weekend-morning-time/weekend afternoon-time	1	EPAPA [33]

ENERGY European energy balance research to prevent excessive weight gain among youth, *EPAPA* Evaluation and Promotion of Adolescent Physical Activity, *EYHS* European Youth Heart Study, *HBSC* health behaviour in school-aged children, *ICAD* International Children's Accelerometry Database, *IDEFICS* identification and prevention of dietary and lifestyle induced health effects in children and infants, *CPM* counts per minute, *min* minutes, *LPA* light-intensity physical activity, *MPA* moderate-intensity physical activity, *VPA* vigorous-intensity physical activity, *MVPA* moderate- to vigorous-intensity physical activity

Another notable feature was, that all accelerometers used in studies included in this review were from one manufacturer (ActiGraph). This shows that research is making progress to more standardized measures, and these data from the same accelerometer may be more easily comparable [56].

Discussion

The aim of this systematic literature review was to provide an overview of the current literature on the population levels of physical activity in youth in cross-European studies, to present population levels of physical activity in European youth, to provide an overview of methods used in cross-European studies and discuss the impact of different assessment methods. Thirty articles were included, in which the number of European countries included ranged from 2 to 36.

Regarding the reported levels of physical activity across European countries, several observations can be made. First of all, there is substantial variability between countries in overall levels of physical activity and in the prevalence of compliance to recommended physical activity levels in youth. In European countries for which data was reported in the included articles, 5 to 47% of children and adolescents complied with the recommended levels of physical activity when measured subjectively, which was consistent with previous research [55]. The objectively measured data ranged from 0 to 60% of youth meeting physical activity recommendations; depending on the intensity thresholds that were used. In previous reviews, results suggested prevalence data between 0 and 100% [55, 56]. Generally, boys were more active than girls and younger children were more active than adolescents. This is consistent with previous literature [57].

These differences may partly be caused by differences in assessment methods used or in sampling methods, but may also be partly caused by true differences in national physical activity levels. This can be illustrated for accelerometer data by the ICAD study, which cleaned, reduced and processed data the same way (and thereby reduced the amount of variability caused by the measurement methods) and found substantial variation between countries [47, 48]. For subjectively measured physical activity, the HBSC study, which collected and processed data the same way, provides an overview of true variation of compliance to physical activity guidelines in 36 European countries [46]. These differences can possibly be caused by cultural differences or differences in physical activity policies between countries (e.g. not all European countries provide the same amount of physical education lessons in school [58]).

A large number of assessment methods have been used in cross-European studies, when assessing physical activity. The use of different methods likely explain some, but not all, of the variability between countries in overall levels of physical activity. For example subjective measurements tend to overestimate measures of physical activity compared to objectively measured physical activity [55]. Nevertheless, subjective measurement methods remain important to measure the context in which physical activity takes place. In this systematic review the subjectively measured data revealed some variability when data were reported in min per day of MVPA. This might well be due to the discrepancy in the questions used to examine total amount of MVPA daily. For example, to examine the total amount of physical activity some questionnaires included more domains (such as: leisure time physical activity, active transportation, physical activity at school) of physical activity than others. Therefore, a minimum requirement for cross-country comparisons include the use of validated, reliable, back-translated, culturally adapted and standardised questions when assessing population levels of physical activity in youth.

Additionally the objectively measured data revealed that when data are presented in minutes per day of MVPA, substantial variation in the reported levels of MVPA in youth is observed. A major factor in this variation are the different intensity thresholds used in the different articles to define MVPA from the accelerometer data. Five different intensity thresholds were used to define MVPA measured with accelerometers in children ranging from >1000 CPM to >3000 CPM and four different intensity thresholds were used in adolescents ranging from >1500 CPM to >3000 CPM. Therefore, different conclusions will be drawn on levels of physical activity in youth depending on which intensity threshold is used. In a previous review a similar range, of intensity thresholds to define MVPA, was reported [56]. Nevertheless, most articles published after 2011 used the intensity thresholds defined by Evenson et al. [59] which were recommended by Trost et al. [13]. This clearly illustrates that research is evolving to more similar methodologies regarding intensity thresholds used for ActiGraph accelerometers.

Consequently, average daily counts per minute (CPM) is a more comparable measurement outcome, as this is not influenced by the specific intensity thresholds that are used. However, this outcome is influenced by data reduction methods, such as the definition of non-wear time and wear protocol (e.g. overnight). Furthermore, this outcome needs calibration in order to be converted into a meaningful outcome such as minutes spent in MVPA [60].

Additionally, different types and models of the same type of accelerometer may produce different results for the same acceleration which need to be considered when interpreting accelerometer derived physical activity data

[61]. However, others have concluded that different models of the Actigraph accelerometer yield comparable results [62–66].

No data were available for some countries. These countries should be included in future international studies. Only articles based on HBSC data [39–46] included a broad range of countries (27–36), with all other articles reporting on less than 10 countries. This implies that the HBSC study is the only study that reports reasonably comprehensive data on physical activity levels of youth across Europe. The HBSC survey (01/02) asked about physical activity level with one question on physical activity in the previous week (i.e. "Over the past 7 days, on how many days were you physically active for a total of at least 60 min per day?") and one on a typical week (i.e. "Over a typical or usual week, on how many days are you physically active for a total of at least 60 min per day?"). In the HBSC studies conducted in 04/05, 09/10 and 13/14 only one question remained (i.e. "On how many days over the past week were you physically active for a total of at least 60 min per day"). These questions (developed by Prochaska et al. [67]) were stated to be a reliable (ICC: 0.77) tool to measure total MVPA in youth and were found to relate significantly with accelerometer data ($r = 0.40$, $p < 0.001$) [67].

Strengths and limitations

A possible limitation of this systematic literature review was that only articles in English were included, thereby possibly missing on relevant articles written in another language. The choice of the databases that were searched and additional search strategies could have led to possible missed articles. In this review only articles reporting on total physical activity and leisure time physical activity were included. A selection of other domains such as active transportation or sport participation may have provided a different result.

We only included studies comprising at least two European countries, thereby excluding all national studies. This was decided as national studies often do not use standardised self-report instruments and data reduction and processing methods are diverse, which limits comparability between countries [16, 68]. Objectively measured physical activity data from national studies may have been better comparable than subjectively measured physical activity data. However, differences in sampling methods and data cleaning and –reduction procedures may limit cross-country comparisons. Harmonization of data prior to comparison between countries is possible and should be the recommended practice [16]. Another limitation of this systematic review was that we excluded all articles that measured physical activity in youth in multiple European countries but did not report levels of physical activity separately per country. Such an example is the HELENA-study (Healthy lifestyle in Europe by nutrition in adolescence) [69].

The most important strengths of this review are its systematic character and profound review process. The search protocol was not adjusted throughout the entire review process. The search was performed for the four reviews (on physical activity in youth, physical activity in adults, sedentary time in youth and sedentary time in adults) together. This provided a solid search strategy with the maximum likelihood of capturing all relevant articles. The study selection, data extraction process, and quality assessment were performed by two researchers, with initial disagreement being resolved by a third researcher.

Recommendations for future research

This review shows that there is an urgent need for international consensus regarding data-cleaning, reduction and processing rules for accelerometer data and for standardization of questions used to assess physical activity in youth. This can be done by building on previous work, for example the International Children's Accelerometry Database (ICAD) project pooled individual accelerometer data files and cleaned, reduced and processed it using standardized methods [70]. This can be used as a good starting point for future international guidelines on cleaning, reducing and processing accelerometer data, to assure that outcome variables across studies can easily be compared. Additionally consensus regarding intensity thresholds for defining different levels of physical activity intensity based on accelerometer data is needed. Trost et al. [13] evaluated the validity of 5 different intensity thresholds used to define MVPA with ActiGraph accelerometers in youth and used indirect calorimetry as reference. They recommend to use the intensity threshold as proposed by Evenson et al. [59] (i.e. 2296 CPM) to define MVPA measured with ActiGraph accelerometers in children and adolescents. As currently, most researchers are already using this intensity threshold, this could be a point of departure for future international consensus on ActiGraph accelerometer intensity thresholds. Furthermore, many recent accelerometers have the capacity to store the raw acceleration data in non-compressed form, eliminating the loss of precision caused by data compression methods including the use of "counts" or "epochs". Thereby removing the need for "counts" based intensity thresholds, and allowing the possibility of identifying specific activities from the accelerometer data using neural networking or machine learning to identify activities followed by the use of "look up" tables to find an associated energy cost [71, 72].

Additionally there is a wide range of questionnaires available to assess physical activity and all questionnaires have inherent limitations. There are still many differences

in data administration, data cleaning and which domains of physical activity (such as: active travel, leisure time, physical activity at school) are questioned. Therefore harmonization is needed and valid and reliable questionnaires should be used in future research.

When guidelines are used to define prevalence rates of physical activity, we recommend to use the WHO [1] guidelines of 60 min MVPA per day (including vigorous-intensity physical activities at least three times a week). Additionally, we recommend future research to report data separately per country to enable comparison between countries.

Conclusion

The present review shows that the available cross-European studies on physical activity in youth used widely varying objective and subjective physical activity assessment methods, different definitions of intensity of physical activity, and various outcome variables. Substantial variation in levels of physical activity and low compliance to physical activity recommendations in youth between countries were reported for subjectively and objectively measured physical activity. The objectively assessed physical activity data varied substantially among articles due to the intensity thresholds used. The results highlight the need to standardize or harmonize data reduction methods, methods to assess physical activity and outcome measures used in physical activity research among youth across Europe. A Pan-European surveillance system should be aimed for, combining accelerometer-based measures of physical activity with domain specific physical activity questionnaires to gain information on the type and context of physical activity.

Additional files

Additional file 1: PRISMA checklist. Checklist for systematic review according to PRISMA guidelines. (DOCX 25 kb)

Additional file 2: The complete search string. (DOCX 11 kb)

Additional file 3: Data extraction file. The complete data extraction file. (XLSX 91 kb)

Additional file 4: Quality assessment file. (DOCX 17 kb)

Abbreviations

ALSPAC, Avon Longitudinal Study of Parents and Children; B, boys; BMI, body mass index; BTS, bouts; CH, cohort; CPM, counts per minute; CS, cross-sectional; CSCIS, Copenhagen School Child Intervention Study; DEDIPAC, DEterminants of Diet and Physical ACtivity; E.M.A., ecological momentary assessment; ENERGY, European energy balance research to prevent excessive weight gain among youth; ENG, England; EPAPA, Evaluation and Promotion of Adolescent Physical Activity; EYHS, European Youth Heart Study; FAS, family affluence scale; FL, flanders; Ft, full-time employed mother; FYRM, The former Yugoslav Republic of Macedonia; G, girls; HBSC, health behaviour in school-aged children; ICAD, International Children's Accelerometry Database; IDEFICS, Identification and prevention of dietary and lifestyle induced health effects in children and infants; ISCED, International Standard Classification of Education; ISCOLE, The international study of childhood obesity, lifestyle and the environment; KISS, Kinder Sportstudie; LPA, light-intensity physical activity; LT, longitudinal; MAGIC, Movement and Activity Glasgow Intervention in Children; min, minutes; MPA, moderate-intensity physical activity; MVPA, moderate- to vigorous-intensity physical activity; n, non-employed mother; n. r., not reported; PEACH, Personal and Environmental Associations with Children's Health; PEL, parental education level; Pt, part-time employed mother; SC, Scotland; SES, socio-economic status; SPEEDY, Sport, Physical activity and Eating behaviour, Environmental Determinants in Young People; UEM, University Education Mother; VPA, vigorous-intensity physical activity; WAL, Wales; WHO, World Health Organisation; WR, Walloon Region

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Authors' contributions

MV, AL and LvH conducted the search, article selection, data extraction and quality assessment and drafted the manuscript. JL, IH, IDB, BD, AD, UE, JB, HvdP conceptualized and designed the study. All authors were involved in critically revising the manuscript for important intellectual content and have read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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Ethics approval and consent to participate

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CHAPTER 2

USE OF PUBLIC OPEN SPACES IN FLANDERS

CHAPTER 2.1.

ACTIVE USE OF PARKS IN FLANDERS (BELGIUM): AN EXPLORATORY OBSERVATIONAL STUDY

Linde Van Hecke, Jelle Van Cauwenberg, Peter Clarys, Delfien Van Dyck, Jenny Veitch, Benedicte Deforche

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Active Use of Parks in Flanders (Belgium): An Exploratory Observational Study

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Abstract: Parks have the potential to increase physical activity at the community level by providing opportunities to be active. In order to inform interventions to promote physical activity in parks, insight is needed concerning park user characteristics, the activity level of park users, the types of activities performed and associations between park areas and temporal variables with observed physical activity levels. Park user characteristics (sex, age, ethnicity and activity level) were recorded within pre-defined park areas in two parks in Ghent (Belgium) using the System for Observing Play and Recreation in Communities (SOPARC). Most park users were male, adult, and engaged in vigorous-intensity physical activity(48%). Activities most observed were biking(38%), sitting(23%) and walking (15%); accordingly, trails were used most and had the highest levels of physical activity compared to other park areas. Parks were used least frequently in the morning, during the weekend and by seniors. Therefore, active park use during morning periods, on weekend days and by seniors should be promoted and urban planners should consider that different park areas can possibly elicit varying activity levels among park users.

Keywords: direct observation; recreation; physical activity; SOPARC; active living

1. Introduction

Worldwide, the number of people with chronic diseases and who are overweight or obese increases continuously [1,2]. Previous research has shown that regular physical activity can prevent becoming overweight or obese [3,4] and is related to a lower incidence of chronic diseases [5]. However, most people do not meet physical activity recommendations [6,7]. Therefore, there is an urgent need for interventions promoting physical activity to enhance population health [5,8]. Previous research suggests that parks can play an important role in promoting physical activity among people of all ages as parks are present in most communities and are generally free to use [9–11]. Parks can provide a suitable setting for organized and non-organized physical activity by providing a variety of physical activity facilities. In an urban environment, parks can also be a destination to visit by foot or bike [12,13]

and thereby have the potential to increase physical activity even if park users engage in sedentary behaviour after arriving at the park.

A substantial amount of research has demonstrated that people living closer to parks perform more leisure-time and park-based physical activity [11,14–18]. Moreover, studies from Australia and the UK have shown that park users are more likely to comply to physical activity recommendations [19,20]. However, there seems to be a difference in physical activity levels depending on the kind of park area or facilities used (i.e., wooded area, tennis court, trails and paths, meadows, open spaces) [21–24]. For example, in the U.S., Besenyi and colleagues (2008) reported higher adult energy expenditure on paved trails and tennis courts than on open spaces, playgrounds and picnic areas. Among children, higher energy expenditure was observed in playgrounds compared to picnic shelters [21].

Moreover, Bedimo-Rung and colleagues emphasized in their conceptual model, that not only structural characteristics of parks, but also individual user characteristics influence park visitation and park-based physical activity (e.g., women are less likely to visit a park compared to men) [9]. Therefore, it would be useful to determine physical activity levels according to the specific park area used and to determine if differences exist based on gender and age of the park users. Park use and park-based physical activity can also differ between workweek and weekend days and according to the hour of the day (e.g., U.S. parks were used less frequently during the morning [11]). However, knowledge is limited in regards to the temporal aspects of park use. Therefore, insight is needed into the time of the day and day of the week during which parks are used less often so that they can be targeted in interventions aimed at increasing park use.

Objective information on park users can be obtained through direct observation tools, of which the System for Observing Play and Recreation in Communities (SOPARC) is the most frequently used [25,26]. Two recent systematic reviews of studies using SOPARC and other observational methods to measure park-based physical activity [26,27] indicated that most research originated from North America and few studies were conducted in Australia [28,29], South America (Brazil) [30,31], Asia (Taiwan, China) [32,33] and Europe (Denmark and Belgium) [34–36]. One study used direct observation to determine the association between park-based physical activity levels and neighbourhood walkability and income in Belgian and U.S. parks. However, they did not report the specific areas of the parks related to physical activity nor the time of the day and day of the week when parks were used most often [34]. Research on park visitation and park-based physical activity in Europe and Belgium is scarce and urban environments in Europe differ from those in other parts of the world. Accordingly, insight is needed on this topic in order to better understand park user characteristics, to define priorities for park renewal and construction, and to inform interventions to promote physical activity in parks.

Therefore, the first aim of this study was to describe the characteristics of park users in Ghent (Flanders, Belgium), the activity levels of park users and the types of activities performed. Secondly, this study aimed to examine the association between park areas, day and time of day, and the observed number of park users and physical activity levels of park users for males and females and children/adolescents and adults/seniors using direct observation methods.

2. Materials and Methods

2.1. Study Setting

Data collection occurred in two parks in Ghent (Flanders, Belgium) from July to October 2014. The city of Ghent has an area of 157.96 km^2 and has 253,266 inhabitants (population density: 1603 inh/km^2) [37], of which 11.6% are under 9 years, 9.7% are 10−19 years, 56.9% are 20−59 years and 21.7% are older than 60 years [38]. The Ghent population consists of 49.4% males [38] with 18.8% part of an ethnic-cultural minority, mostly of Turkish or Bulgarian origin [39]. This study was approved by the Ethical Committee of the University Hospital in Ghent (2015/0550). The two parks comprised areas

of 51,313 m^2 and 31,502 m^2 respectively, and included a variety of features/amenities (i.e., wooded area (=area with lots of trees), grassy area with a playground, pond, trails, etc.).

2.2. Measurements

2.2.1. The Environmental Assessment of Public Recreation Spaces (EAPRS)

The Environmental Assessment of Public Recreation Spaces (EAPRS) tool was used to provide an overview of the park amenities and features. This tool is a comprehensive audit instrument that characterizes the physical environment within public parks [40]. This audit was completed by a researcher prior to the observations.

2.2.2. The System for Observing Play and Recreation in Communities (SOPARC)

The System for Observing Play and Recreation in Communities (SOPARC) was used to obtain direct information on park use and characteristics of the park users. SOPARC has been proven to be a valid and reliable observation tool [25]. Before the observations were conducted, both parks were divided into observable target areas (5−7 areas per park) which represented specific locations within the parks (e.g., wooded area, grassy area with a playground, ponds, trails). On-site observations were conducted for nine days (simultaneous measurements at the two parks), including five weekdays and four weekend days, on different days of the week and at varying times of the day (7:30, 12:30, 15:30, 18:30) [41]. Each observation moment lasted approximately 20−30 min. At these predetermined time points, trained researchers scanned each target area and recorded the following characteristics of the park users: age (child = 0−12 years, adolescent = 13−20 years, adult = 21−59 years and senior $\geq$60 years), gender, ethnicity (Caucasian or non-Caucasian) and activity level (sedentary, moderate or vigorous). Additionally, each area was assessed on its accessibility, usability (e.g., not excessively wet or roped off for repair), equipment (e.g., balls, jump ropes), supervision (adults that are either payed, or volunteer to supervise in a park), provision of lighting and organization of activities. In total, 432 scans were completed across 12 target areas (5−7 areas per park) during 36 observation moments (nine days $\times$ four time points) in each park. Observations were only conducted in neutral to good weather (i.e., no rain) and cancelled observations due to bad weather were rescheduled in the following week on the same day of the week. Three researchers (Linde Van Hecke, Lars Van Elewijck, Silke Van Hoof) conducted the observations; however, only a single observer was present in each park on each day. One researcher (Linde Van Hecke) conducted the observations on all nine days in one of the two parks. The other two researchers (Lars Van Elewijck and Silke Van Hoof), each performed observations on four and five days, respectively.

All target areas were accessible and usable but none were supervised or equipped and all observations took place during daylight hours. Therefore, these variables were not included in the analysis. The variable "organized activities" was also not included in the analyses because of the low prevalence of observing organized activities in the parks (2.3% of observation moments). The target areas which included ponds also had low usage (1.4% of all observation moments) so were not included in the analyses.

2.2.3. Training of the Researchers

The researchers were trained using the SOPARC protocol and training video [42]. The researchers conducted ten test observations in each park (20 in total) which consisted of independent observations that were carried out simultaneously. These were used to establish interrater reliability (IRR) on park user characteristics (i.e., gender, age, ethnicity and level of physical activity) and park characteristics (i.e., accessibility, usability, equipment, supervision, lighting and organized activities). Reliability was defined as good for ICCs ranging from 0.60 to 0.74 and excellent for ICCs higher than 0.75 [43]. Agreement between observers was good to excellent for all user characteristics (ICC = 0.74−1.00). Agreement for the park characteristics was also good to excellent, with the lowest ICC for usability

of the target area (ICC = 0.65). As recommended by Hallgren (2012), all IRR estimates from the test observations had to be good or excellent (>0.60) before the actual observations commenced [43].

2.3. Analyses

In order to analyse the mean physical activity level in each target area during an observation moment, Metabolic Equivalents (METs)/observation/target area were computed for all users, and for the different age (children and adolescents, adults and seniors) and gender subgroups within this area. To do so, the total observed number of park users in each activity level (i.e., sedentary, moderate or vigorous), was multiplied with the corresponding MET value (sedentary = 1 MET, e.g., sitting reading a book; moderate = 3 METs, e.g., walking; vigorous = 6 METs, e.g., jogging). The result of all activity levels was summed and then divided by the total number of observed park users in this area to obtain the mean activity level per person. This approach has previously been used by Van Dyck et al. 2013 [34].

In order to gain insight in gender and age-specific differences in the number of park users and physical activity levels according to the park area, hour of the day and day of the week, analyses were performed for males and females, and due to limited power, for youth (0−20 years) and adults (>20 years) separately rather than for the four age groups. Since all variables were measured at the park area level, it was not possible to examine interaction effects.

Associations of the independent variables (park area and temporal characteristics: week or weekend day, time of the day) with the dependent variables (number of park users and physical activity levels) were examined using multilevel Hurdle models (level 1 = h, level 2 = day, level 3 = target area, level 4 = park) using the package LME4 [44] in R version 3.1.0 (RStudio Team (2016). RStudio: Integrated Development for R. RStudio, Inc., Boston, MA, USA). Hurdle models were used because of the high number of zero observations (i.e., empty target areas). Hurdle models consist of two parts. First, the association between the independent variables and observing at least one park user in the park area was estimated by means of logistic regression analysis (binomial variance and logit link function). This regression coefficient represents the association between the independent variables and the odds of observing a target area where at least one park user was present. Secondly, the model estimated the association between the independent variables and the number of users/activity level for the park areas that were not empty. This regression coefficient represents the proportional change in number of users/activity level of the park users associated with a one-unit difference in the independent variables for park target areas where at least one person was present. Based on the Akaike's Information Criteria (AIC), the variance and link function that best fitted the data were defined (Poisson variance with log link function for count variables, and Gamma variance with log link function for continuous dependent variables). No logistic regression analyses were performed for the dependent variable "activity level", as these would yield identical results as the analysis on the presence of at least one park user. Level of significance was set at $\alpha = 0.05$.

3. Results

3.1. Descriptive Statistics

In total, 837 park users were observed of which the majority were adults (43.9%), 20.7% were children (0−12 years), 25.8% were adolescents (13−20 years) and only 9.7% were aged over 60 years. The majority of participants were male (58.7%), except for the adult category, where gender was distributed equally. Users were predominantly Caucasian (82.8%), almost half were vigorously active (48.2%), 24.7% were moderately active and 27.1% were sedentary (Table 1). Park characteristics assessed using the EAPRS tool are presented in Table 2. The activities that were observed include biking (37.9%), sitting (22.5%), walking (15.1%), playing (7.3%), walking the dog (5.4%), ball sports (5.0%), jogging (3.4%), standing (3.2%), and lying down (0.4%). However, during 57.6% of the observation scans, the target areas had no park visitors present.

Table 1. Observed park user characteristics.

Park User Characteristics	Total		Children		Adolescents		Adults		Seniors	
	n	%	n	%	n	%	n	%	n	%
Park users	837		173	20.7	216	25.8	367	43.9	81	9.7
Male	491	58.7	117	67.6	140	64.8	187	51.0	47	58.0
Female	346	41.3	56	32.4	76	35.2	180	49.1	34	42.0
Caucasian	693	82.8	145	83.8	173	80.1	303	82.6	72	88.9
Non Caucasian	144	17.2	28	16.2	43	19.9	64	17.4	9	11.1
Sedentary	227	27.1	35	20.2	71	32.9	101	27.5	20	24.7
Moderately active	207	24.7	55	31.8	49	22.7	75	20.4	28	34.6
Vigorously active	403	48.2	83	48.0	96	44.4	191	52.0	33	40.7

Table 2. Descriptive park characteristics using the EAPRS audit tool.

Descriptive Characteristics	Park 1	Park 2
Access		
Access to the park is free	Yes	Yes
Neighbourhood immediately surrounding park	Residential	Residential
Entrances	3	3
Bike racks	No	Yes
Parking lots	Yes	No
Sidewalks adjacent to park	Yes	Yes
Roadways trough park	No	No
Trails & paths		
Paved trails present	No	Yes
Unpaved trails	No	Yes
Paths	Yes	Yes
General areas		
Open space	Yes	Yes
Meadows	No	No
Wooded area	Yes	Yes
Pond	Yes	Yes
Water Areas		
Stream/creek	No	No
Swimming pool	No	No
Fountain	No	No
Beach area	No	No
Eating/drinking features		
Water fountain	No	No
Grill/fire pit	No	No
Picnic area	No	No
Vending food/drinks	No	No
Facilities		
Restrooms	No	No
Shelter	No	No
Entertainment venues	No	No
Historical features	No	No
Sitting and resting features (non-trail)		
Benches	Yes	No
Tables	No	Yes
Seat walls	No	No
Bleachers	No	No
Landscaping & General Aesthetics		
Flowers	No	No
Shrubs/bushes	No	No
Landscaping beds	No	No
Views of outside park	No	No
Sculpture of other art	No	No
Trash cans	Yes	Yes
Wildlife area	No	No
Information related features		
Rules/regulation signs	No	No
Maps	Yes	No
Event postings	Yes	Yes
Safety related features		
Telephone	No	No
Play structure & other play components		
Play structure present	Yes (1)	Yes (2)
Seating around play structure	Yes	Yes
Separate play sets for different age groups	No	No
Surface material	Sand	Sand
Things to hang from	Yes	No
Things to slide down	Yes (1)	Yes (1)
Things to climb on, up, or through	Yes (2)	Yes (1)
Things to stand or walk on	No	No
Things to spin	Yes (1)	No
Swings	Yes (1 baby, 1 chair)	Yes (2 chair)
Spring toys	Yes (3 animals)	Yes (2 animals)
Imaginary play structure	No	No

3.2. Associations of the Park Areas and Temporal Characteristics with the Odds of Observing at Least One Park User

The logistic regression model (Table 3) for the total sample shows that the odds of observing at least one park user were higher at midday, in the afternoon and in the evening compared to morning observations. Separate analysis revealed similar results for males and females (not at midday) and for children/adolescents and adults/seniors. The odds of observing at least one park user were higher on trails compared to grassy areas with a playground. This was found in all separate subgroups. The odds of observing at least one park user were lower for wooded areas compared to a grassy area with a playground. When groups were analysed separately, similar results were found for all groups. Compared to a weekday, the odds of observing at least one park user on a weekend were lower. This was only found for adults/seniors in the separate analyses but not for children/adolescents nor when males and females were analysed separately.

3.3. Association of the Park Areas and Temporal Characteristics with the Number of Park Users

This section addresses the results of the second part of the Hurdle models (Poisson models in Table 3) and represents the proportional change in the number of park users associated with the independent variables for park target areas where at least one person was present.

In the total sample, no differences were found in the number of park users during midday compared to morning observations, nor for males, children/adolescents and adults/seniors. However, 57% more females were observed at midday compared to morning observations (95% CI = 1.1−2.3). In the total sample, 109% more park users were observed in the afternoon compared to morning observations (95% CI = 1.7−2.7). This was also found for males, females and children/adolescents but not for adults/seniors. In the total sample, 40% more park users were observed in the evening compared to morning observations (95% CI = 1.1−1.8). This was also found for children/adolescents but not for adults/seniors, females or males. On trails, compared to a grassy area with a playground, no differences were found in the number of park users for the total sample, females and children/adolescents. However, more males and adults/seniors were observed on trails than grassy areas with a playground. In wooded areas, there were 55% (95% CI = 0.3−0.7) less park users compared with grassy areas with a playground. Similar results were found in male and adults/seniors subgroups, but these differences were not observed among females and children/adolescents. No significant differences were found in the number of park users during the weekend compared to weekdays.

3.4. Association of the Park Areas and Temporal Characteristics with Park Users' Activity Levels

The following section describes the results of the Gamma models (Table 4). These analyses were performed for park areas where at least one person was present. In the total sample, among males, children/adolescents and adults/seniors, no differences were found in observed activity levels between morning and midday. The activity level among females was 24% (95% CI = 0.6−1.0) lower at midday compared to the morning. The activity level of the total sample was 24% (95% CI = 0.6–0.9) lower in the afternoon compared to morning observations. Similar results were found for females and adults/seniors, but not for males and children/adolescents. No difference in activity level was found between evening and morning observations. Activity levels for the total sample (and all subsamples) was 73% (95% CI = 1.5–2.1) higher on trails compared to grassy areas with a playground. No difference in activity level was found between wooded areas compared to grassy areas with a playground for the total sample and all subsamples. Analyses of the total sample, females, children/adolescents and adults/seniors revealed no difference in activity level between the weekend and weekdays. Activity level among males was 21% higher in the weekend (95% CI = 1.0−1.4).

Table 3. Hurdle models.

Independent Variables	Total Number of Park Users				Male Park Users				Female Park Users			
	Logistic Regression [a]		Poisson Model [b]		Logistic Regression [a]		Poisson Model [b]		Logistic Regression [a]		Poisson Model [b]	
	OR	95% CI	Exp. B	95% CI	OR	95% CI	Exp. B	95% CI	OR	95% CI	Exp. B	95% CI
Time of day (ref = morning)												
lunch	4.40 ***	1.94–9.99	0.98	0.76–1.29	7.29 ***	3.01–17.68	0.71	0.49–1.02	1.38	0.63–3.03	1.57 *	1.06–2.33
afternoon	6.82 ***	2.96–15.62	2.09 ***	1.65–2.66	15.46 ***	6.21–38.48	1.53 *	1.10–2.12	3.76 ***	1.72–8.23	2.01 ***	1.40–2.88
evening	4.46 ***	1.97–10.09	1.40 **	1.09–1.81	6.01 ***	2.50–14.42	1.14	0.81–1.61	3.26 **	1.49–7.10	1.36	0.92–1.99
Type of park area (ref = grassy area with a playground)												
trail	13.09 ***	4.24–40.41	1.79	0.90–3.59	15.79 ***	4.38–56.96	2.09 *	1.12–3.92	4.53 *	1.37–14.96	1.43	0.96–2.11
wood	0.05 ***	0.02–0.14	0.45 ***	0.31–0.67	0.06 ***	0.02–0.15	0.65 *	0.43–0.97	0.02 ***	0.00–0.12	0.55	0.18–1.69
Day type (ref = week)												
weekend	0.38 *	0.15–0.98	0.96	0.63–1.45	0.72	0.26–1.92	1.09	0.72–1.66	0.46	0.20–1.06	0.75	0.53–1.07

Independent Variables	Child/Adolescent Park Users				Adult/Senior Park Users			
	Logistic Regression [a]		Poisson Model [b]		Logistic Regression [a]		Poisson Model [b]	
	OR	95% CI	Exp. B	95% CI	OR	95% CI	Exp. B	95% CI
Time of day (ref = morning)								
lunch	4.86 **	1.71–13.79	2.05	0.96–4.34	3.05 **	1.35–6.88	0.89	0.66–1.21
afternoon	17.81 ***	6.35–49.98	4.91 ***	2.38–10.11	4.54 ***	2.00–10.29	1.17	0.88–1.54
evening	10.78 ***	3.86–30.06	3.28 **	1.56–6.89	2.45 *	1.09–5.50	1.09	0.82–1.46
Type of park area (ref = grassy area with a playground)								
trail	4.26 ***	1.81–10.05	1.66	0.82–3.34	8.15 ***	2.65–25.00	1.51 *	1.08–2.11
wood	0.09 ***	0.03–0.23	0.67	0.43–1.05	0.04 ***	0.01–0.12	0.53 *	0.31–0.92
Day type (ref = week)								
weekend	1.37	0.49–3.83	0.82	0.48–1.40	0.29 **	0.13–0.68	0.96	0.77–1.20

[a] The logistic regression model estimated the association of the independent variables with the odds of observing park users in the park areas. [b] The Poisson models (Exp. B) estimated the proportional difference in number of users associated with a one-unit difference in the independent variables for park target areas where at least one person was present. OR = Odds Ratio, CI = Confidence interval, Exp. B = Exponent of B, ref = reference category. * $\alpha < 0.05$, ** $\alpha < 0.01$, *** $\alpha < 0.001$.

Table 4. Gamma models.

Independent Variables	Average PA Level for All Park Users		Average PA Level for Male Park Users		Average PA Level for Female Park Users		Average PA Level for Child/Adolescent Park Users		Average PA Level for Adult/Senior Park Users	
	Exp. B	95% CI	Exp. B	95% CI	Exp. B	95% CI	Exp. B	95% CI	Exp. B	95% CI
Time of day (ref = morning)										
lunch	0.85	0.69–1.04	1.02	0.79–1.30	0.76 *	0.59–0.98	0.83	0.52–1.33	0.80	0.64–1.00
afternoon	0.76 **	0.62–0.93	0.87	0.69–1.11	0.78 *	0.61–0.98	0.69	0.45–1.07	0.76 *	0.62–0.95
evening	0.87	0.71–1.07	0.86	0.67–1.11	0.91	0.73–1.17	0.78	0.50–1.21	0.83	0.66–1.04
Type of park area (ref = grassy area with a playground)										
trail	1.73 ***	1.45–2.06	1.96 ***	1.67–2.30	1.69 ***	1.37–2.08	1.54 **	1.19–2.00	1.92 ***	1.58–2.34
wood	1.01	0.78–1.32	1.01	0.80–1.28	1.29	0.85–1.94	0.99	0.69–1.43	1.05	0.79–1.41
Day type (ref = week)										
weekend	1.11	0.93–1.33	1.21 *	1.03–1.42	0.99	0.78–1.25	1.20	0.98–1.48	1.02	0.78–1.32

The Gamma models (Exp. B) estimated the proportional difference in activity level associated with a one-unit difference in the independent variables for park target areas where at least one person was present. All Gamma models were fitted using the log link function. PA = physical activity, Exp. B = Exponent of B, CI = Confidence interval, ref = reference category. * $\alpha < 0.05$, ** $\alpha < 0.01$, *** $\alpha < 0.001$.

4. Discussion

Sufficient physical activity contributes to better health status across the lifespan, and parks have the potential to increase physical activity at the community level by providing opportunities for physical activity. This study described the characteristics of park users in Ghent (Flanders, Belgium), the activity levels of park users, the type of activities performed and the associations between park areas and temporal variables with observed physical activity levels. The majority of the observed visitors were males, adults and were engaged in vigorous-intensity physical activity with cycling, sitting and walking as the most observed activities. Seniors were the least represented age group and the smallest number of park visitors were observed in the morning and during weekends. Activity levels were higher on trails and lower in wooded areas compared to grassy areas with a playground.

Overall, the parks in this study had low levels of visitation (58% of observation moments, parks were empty), which could possibly be caused by the small amount of features and amenities present in the parks (according to the audit that was performed). However, these parks were selected because they did not have atypical features (for Flanders) and had not been renovated recently. Moreover, organized activities were limited and supervision and provision of equipment was lacking. This indicates that there are many opportunities to improve the attractiveness, use and physical activity within these parks. When developing programs to increase park visitation, it is important to determine which specific target groups are currently underrepresented and could benefit from extra attention, and which park areas are associated with higher activity levels. In addition, associations of park areas and temporal variables with the number of park users and physical activity levels were examined according to gender and age group.

Most park users in this study were male (58.7%), which is consistent with previous research using observational measurements in Belgium [34] and with the results of a review by Evenson and colleagues [27]. However, this gender difference was only present for children, adolescents and seniors, and not for adults, where the distribution was more equal between males and females. For children and adolescents, this gender difference may be attributed to higher independent mobility among boys compared to girls [45] or by the nature of the activities boys and girls participate in (i.e., girls like to go shopping, whereas boys prefer to do sports [46]). The age distribution of the park users was comparable with those from observational research from the U.S., with the majority of park users being adults and only a minority being seniors. In this study, more adolescents were observed than in U.S. parks [11,25,34,47,48] and Australian parks [28], but less adolescents than in previous Belgian research [34]. The relatively low percentage of seniors observed in the parks (9.7% of the park users were older than 60, compared to 21.7% of the Ghent population [38]) indicates that extra effort may be needed to encourage seniors to use parks more often. The city of Ghent has many parks spread throughout the city and they should therefore be readily accessible or within close proximity to home for most residents. However, the current park features/amenities may not encourage seniors to visit the parks or access to the parks may be difficult (i.e., uneven footpaths [49]) and discourage visitation. Future studies need to explore which park features are important for park use among seniors. Of the park users observed, 82% were Caucasian, which is representative of the Ghent population and similar to previous research [34,39].

In this study, almost half of the observed park users were observed engaging in vigorous-intensity physical activity, whereas in previous observational studies in the U.S., most park users were sedentary [11,21,22,25,34,47,48]. In Australia, most park users were standing or moderately active [28]. Sedentary activities in parks can have social benefits [50] and even people who use parks for sedentary activities may travel to the park using active transport such as by foot or bike [12,13]. Previous research in adolescents indicated that adolescents prefer to alternate between active and sedentary activities [51]. Therefore, parks should be designed so that they support both physical activity and sedentary activities and provide sufficient infrastructure to support active travel to the park. The high number of vigorously active users in this study could possibly be attributed to the high number of cyclists observed in the parks (38% of park users were cycling). However, it must be noted that most

cyclists were only passing through the park to travel elsewhere suggesting that the parks offered an alternative, convenient and/or safe cycling route. Policy makers should take this into account, as cycling is often forbidden in parks. At least one cycle lane in each park could be a useful strategy for future park development. The other activities that were frequently observed in the parks in this study were sitting (23% of users), walking (15% of users) and playing active games such as hide and seek (7% of users). This could indicate that apart from using a park to cycle through, parks in Flanders are used mostly as a place to relax rather than to engage in intensive sports or to work out, which is consistent with the conclusion by Van Dyck et al. (2013) [34]. However, the qualitative results of a study conducted by Cohen and colleagues (2007) revealed that U.S. parks were used for sedentary activities such as picnics (22% of users), as well as for more active purposes such as playing basketball (15% of users) or as spectators of an organized activity (13% of users) [11]. This indicates that cultural differences may exist in park activities between Europe and the U.S.

Less participants were observed during morning periods and during weekends. However, the activity levels were lower during the day (for females and all age groups) and higher on the weekend for males. This may indicate that when less people are present in the park, park users are more likely to engage in physical activities instead of sitting behaviours, or park users may have different intentions when they visit a park in the morning (e.g., they are cycling to school/work) compared to during the day or during the weekend compared to a weekday. Other studies have also shown park visitation to be lower in the morning [11,28]. However, an Australian study on park use in metropolitan parks reported more visitors during the weekends [28] than on weekdays, which is contradictory to our results. These contradicting results could be due to differences in size and location of the parks included in the Australian study: large metropolitan parks outside of the city (=long travel time) compared to small parks located in urban areas. If the findings of the current study are confirmed in future research for small parks, future interventions promoting park use in small urban parks could possibly target morning and weekends as these are the moments small urban parks are currently used least.

The odds of at least one park user being present were higher on trails and lower in wooded areas compared to grassy areas with a playground. No difference was found in the number of children/adolescents observed on trails and in wooded areas compared to grassy areas with a playground. This is surprising as it could be hypothesized that children and adolescents would use a grassy area with a playground more often than a trail [21,52]. This may be the result of analysing children and adolescents together, thereby age-dependent differences may have been overlooked. Future research should allow for analyses for each age group separately by including more parks. Furthermore, the activity level of all user groups was higher on trails compared to grassy areas with a playground. This could possibly be due to the high number of cyclists on the trails. This supports previous research from Canada and Denmark that revealed a significant association between the presence of a walking/cycling path and park-based physical activity in adults [53,54] and research from Besenyi et al. (2013) that revealed the highest energy expenditure among adults on paved trails in U.S. parks [21]. A possible approach for future urban planning may be to link existing urban parks with each other using trails to encourage walking and cycling [53,55]. This could be a suitable strategy for European historical cities such as Ghent, which are often densely built with many individual small urban parks.

The higher activity level of children and adolescents on trails compared to grassy areas with a playground could be explained by the nature of the playgrounds. In the studied parks, the playgrounds consisted of components that primarily facilitate sedentary behaviour (such as a sand pit) rather than encourage physical activity. Furthermore, playgrounds are often designed for younger children [51]. Hence, playgrounds that include equipment such as climbing structures or basketball hoops that encourage physical activity should be chosen over playgrounds that include equipment that promotes sedentary behaviour [56]. Previous qualitative research in adolescents indicated that adolescents often

visit public open spaces with younger siblings [51]. Therefore, it is also important that playgrounds are designed to cater for the needs of multiple age groups.

A possible explanation for higher activity levels of females on trails compared to grassy areas with a playground could be that when females are present at a grassy area with a playground, they often engage in standing and sedentary activities to supervise children at the playground [11]. Cohen and colleagues (2007) have recommended the provision of equipment that provides opportunities for carers of children to be active near playgrounds while supervising their children (e.g., walking paths around the playgrounds, or adult fitness stations) [11]. This could be a valuable strategy to increase physical activity levels in parks among carers of children.

Earlier findings highlight the importance of the presence of trees in parks as this is associated with physical activity [54,57], mental health [58] and the provision of shade [59]. However, in this study, the wooded areas had the lowest number of users (55% lower than trails). This low number of users may be due to the density of the wooded area (in this study the wooded area had a high density of trees) which may have a negative influence on park users' perceptions of safety, since secluded areas may create feelings of insecurity [57,60]. Therefore, park designers should ensure the presence of trees but avoid creating densely wooded areas.

4.1. Strengths

This study used a valid and reliable observation tool (designed specifically for parks) to assess park use, park-based physical activity and characteristics of the park users [25]. All observers received training to use this tool and interrater reliability was confirmed before starting the observations. Additionally, the same observers performed the observations in both parks at exactly the same time and on the same days. Cohen et al. (2011) recommended at least four days of observation to obtain robust measures of park use and user characteristics [41]. In this study, observations were performed on nine days.

4.2. Limitations

This study only comprised two parks in Ghent and the findings should be considered exploratory. The audit of park characteristics was not validated by a second observer, and this should be considered as a limitation of the study. In the future, park audits should include an assessment of the park areas separately and an assessment of the quality and condition of the park features and amenities. In addition, to provide a better understanding of the results, future research could include qualitative methods to study the perceptions of park visitors. The observations only took place during neutral to good weather, therefore no conclusions could be drawn about the association between weather and park use. In addition, the observations were performed in summer and beginning of autumn (July to October) so no seasonal effect could be examined and results may be different in other seasons. The observations took place at fixed moments in time on nine days and other days and moments could possibly provide different results. Further, no additional information (such as living close to the park, income or transport mode to the park) was collected from the park users. A final methodological limitation is the estimation of the park users' age which may have led to the misclassification of park users into different age groups.

5. Conclusions

Flemish parks provide many opportunities for physical activity at the community level but are currently underutilized. More specifically, (active) park use during morning periods and weekends and by all age and gender groups with special attention to seniors should be promoted. Furthermore, trails were found to be the park area that was used most and at the highest level of physical activity. When designing or renewing urban parks, urban planners and policy makers should take into account that different park areas may encourage varying physical activity levels among park users and playgrounds may need to be designed or refurbished in order to encourage physical activity. Future research should

build on this exploratory research by including a larger number of parks with greater variety of park areas and by conducting natural experiments to gain insight into the causal relationship between specific park characteristics, park visitation and park-based physical activity.

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CHAPTER 2.2.

FACTORS RELATED WITH PUBLIC OPEN SPACE USE AMONG ADOLESCENTS: A STUDY USING GPS AND ACCELEROMETERS

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RESEARCH Open Access

Factors related with public open space use among adolescents: a study using GPS and accelerometers

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Abstract

Background: Low physical activity levels and high levels of sedentary time among adolescents call for population wide interventions. Public open spaces can be important locations for adolescents' physical activity. This study aimed to describe the prevalence, frequency and context of public open space visitation and to gain insight into the individual, social and physical environmental factors associated with public open space use among 12- to 16-year-old Flemish (Belgian) adolescents.

Methods: Global positioning system devices, accelerometers and one-on-one interviews were used to measure location-specific activity levels, time spent at, reasons for using and accompaniment at public open spaces among 173 adolescents. Multilevel hurdle and gamma models were used to estimate the associations between the independent variables (age, gender, ethnicity, education, sport club membership and accompaniment) and the amount of time, sedentary time, light-, moderate- to vigorous- and vigorous-intensity physical activity at public open spaces.

Results: Three out of four participants had visited a public open space (for recreational purposes) and participants were most often accompanied by friends/classmates. Mainly public transportation stops/stations were used, and subsequently the most reported reason for public open space use was "to wait for something or someone". Furthermore, boys, younger adolescents, non-western-European adolescents and lower educated adolescents were more likely to use public open spaces. Additionally, boys and younger adolescents were more likely to accumulate physical activity at public open spaces. The only social environmental variable associated with time spent at public open spaces was accompaniment by siblings: adolescents spent more time at public open spaces when accompanied by their siblings.

Conclusions: Public open spaces may be effective areas to promote physical activity among groups at risk for physical inactivity (i.e. low educated and non-western-European adolescents). Additionally, girls and older adolescents were less likely to visit and be physically active at public open spaces. Therefore, urban planners should consider adding attractive features, in order to encourage physical activity among girls and older adolescents at public open spaces. Furthermore, creating public open spaces that are attractive for youth of all ages could contribute to adolescents visiting public open spaces accompanied by siblings.

Keywords: Global positioning device, Physical activity, Sedentary time, Youth, Leisure time, Public spaces

Background

The World Health Organisation (WHO) recommends adolescents to engage in 60 min of moderate- to vigorous-intensity physical activity (MVPA) daily [1] in order to obtain health benefits such as lower risk for overweight and obesity, diabetes type 2, high blood pressure and depressive symptoms [2–5]. In addition, adolescents engaging in extended periods of sedentary time (i.e. time spent sitting or lying down at low energy expenditure [6]) are at higher risk for higher Body Mass Index

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(BMI), decreased fitness and lower psychosocial health [7, 8]. However, during the transition from childhood to adolescence a steep decline in physical activity (physical activity) levels [9–11] and an increase in sedentary time occurs [10, 11]. Subsequently, more than half of the adolescent population worldwide does not meet the physical activity recommendations [12–14] whilst European adolescents' sedentary time rises to 4–8 h per day on average [15]. Furthermore, healthy behaviours concerning physical activity and sedentary time developed in adolescence are known to track into adulthood, so being sufficiently active and having low levels of sedentary time during adolescence are of high importance [16–18].

Consequently, there is a need for population wide interventions to increase adolescent physical activity levels and decrease sedentary time. In the past, mostly individually-oriented models were used for intervention development [19]. During the last decade however, a shift has been made to socio-ecological models, which emphasize the interactions between individuals and their physical and socio-cultural environment [19, 20]. The different layers of the socio-ecological model are build up around four active living domains where adolescents can be active: at home, at school, during active transportation, and during leisure time [20]. Leisure time, physical activity can occur in an organized setting such as sport clubs or in non-organized settings such as at home, in streets, parks and playgrounds. Little is known about the locations where adolescents' non-organized leisure time physical activity (away from home) takes place and the need for more information on location-specific physical activity levels has been emphasized previously [21].

Studies in the US have shown that public open spaces (POS) are used for physical activity and recreational activities among children, adolescents and adults [22–24]. They are suitable for non-organized physical activity as they are public spaces that are freely accessible to all people, without entrance fee and present in most communities [24–26]. POS can have different appearances such as parks, playgrounds and squares, but also streets, vacant lots and parking lots. POS may be especially important for adolescents under the age of sixteen because they do not have the possibility to drive a car or moped and are, therefore, still limited in their ability to visit places located at greater distance from their residence and have to rely more on public transportation. Moreover, qualitative research has indicated that adolescents attach great importance to POS as a place where they can spend time without parental supervision or to be away from the bustle at home or school [27, 28].

On the one hand, a POS can be a suitable location for physical activity (and thereby directly increase overall physical activity levels), but on the other hand, a POS can also be a destination that adolescents can visit using active transportation (and thereby increase overall physical activity levels through active transportation) [7, 8]. This implicates that when only physical activity in POS would be considered in research (and thus not including physical activity during trips to and from POS), an underestimation of the physical activity related to POS visitation would be made. Therefore, physical activity accumulated during trips to and from POS should be included in research concerning POS use among adolescents, as these can contribute to overall activity levels even if adolescents do not accumulate physical activity in POS.

Research on POS use among adolescents is limited, but some studies have emerged recently. An Australian survey study reported almost 40% of 13-year old adolescents to have used a park at least once a week during the past 3 months. Additionally, only 12% of the adolescents reported not to have visited a park in the past 3 months [29]. Furthermore, a US study among 11- to 14-year-old adolescents using accelerometers and global positioning system (GPS) devices reported that an average of 45 min was spent daily on streets and sidewalks, 25 min at playgrounds and 17 min in parks [30]. A Danish study among 11–16-year olds with similar methodology reported lower levels of POS use, with a median of only 11.7 min/day spent at school grounds (during leisure time), 5.2 min/day in urban green space, 0.0 min/day at playgrounds and 0.0 min/day at sport facilities [31]. However, the differences in POS use between the two studies can be attributed to the fact that active transport to POS and in POS was included to calculate time spent in POS in the US study, while this was not the case in the Danish study.

However, research on the prevalence and frequency of POS visitation, the activity levels in POS, types of POS used and reasons for POS visitation among adolescents remains scarce, especially in Europe. Therefore, additional research is needed to gain insight into the prevalence and frequency of POS visitation and the activity levels in POS. Furthermore, the types of POS that are used and reasons for POS visitation should be explored in order to better understand the different aspects of (active) POS use.

As mentioned above, socio-ecological models emphasize the importance of individual-, physical- and social environmental factors to explain physical activity behaviours and sedentary time. Currently, information is lacking about factors associated with time and physical activity in POS whilst (to our knowledge) no studies have investigated the factors associated with sedentary time in POS. Because sedentary time is independently related to health problems [12, 13], identifying factors associated

with sedentary time in POS is especially important. Identifying the physical and social environmental factors that could induce sedentary behaviour in POS enables to define the necessary strategies to reduce sedentary time at public open spaces. Additionally, this allows to target specific population groups at risk for sedentary time in POS.

Two Danish studies using GPS and accelerometers showed that older adolescents (mean age 14.2) spent less time [31] and less MVPA [32] at school grounds during leisure-time and more time and MVPA at sport facilities and shopping centres compared to younger adolescents (mean age 12.4) [31]. Furthermore, boys aged 11- to 16-year-old spent more time at sport facilities, accumulated more MVPA at school grounds during leisure time [31, 32] and less MVPA at playgrounds and urban green space compared to girls [32]. Furthermore, a Canadian study using GPS and accelerometers indicated that adolescents living in suburban areas performed more MVPA in POS locations such as green spaces or shopping malls compared to adolescents living in urban and rural areas, whilst no differences were found in MVPA at different POS locations according to adolescents' Socio-Economic Status (SES) [33]. These studies indicate that individual factors such as gender and age could possibly be associated with time spent and physical activity in POS whereas, no previous research has looked into the individual factors associated with sedentary time in POS. Furthermore, it is possible that the social environment (e.g., accompaniment in POS) is associated with adolescents' time, sedentary time and physical activity in POS, however, no studies have investigated this matter. Additionally, some physical environmental factors associated with physical activity in POS, have been identified, whereas no research has studied the associations for environmental factors with sedentary time in POS. Recent observational research has indicated that different park areas such as playgrounds, open fields or sport fields were associated with different activity levels across all age groups [34–37]. This evidence suggests associations of individual, social- and physical environmental factors with time and physical activity in POS among adolescents. However, European research is limited and additional insight is needed into the factors associated with sedentary time in POS among adolescents.

Many of the studies investigating the association between POS availability, POS use and physical activity levels have used questionnaires, geographical information systems (GIS) or audits of POS in the participants' neighbourhood [23, 38–41], assuming that these are the locations that are most frequently used. However, adolescents may use other POS than those closest to home and, therefore, it is important to use methods such as diaries or GPS-measures that allow to investigate the locations that are actually used by the adolescents. GPS devices have been identified as more accurate compared to activity diaries [42–44]. Furthermore, when GPS devices are combined with accelerometers, it is possible to objectively measure location-specific physical activity [45].

Summarized, evidence on adolescents' POS use and its associated individual, physical and social environmental factors is limited, with most studies originating from North-America and Australia. Only two studies originate from Europe. Most of the existing studies included measures of POS use, some included measures of physical activity in POS, whilst none included measures of sedentary time in POS. Furthermore, many studies have used methods that cannot capture the specific POS that is used. POS can be suitable locations for physical activity among adolescents. However, in order to develop interventions to promote physical activity and reduce sedentary time in POS, insight is needed into the use of POS, physical activity and sedentary time in POS and into the factors associated with POS use, physical activity and sedentary time in POS. Therefore, this study used GPS devices and accelerometers in order to (1) describe the prevalence, frequency and context (i.e. company, locations and reason) of POS visitation and (2) gain insight into the individual, social and physical environmental factors associated with time, sedentary time and physical activity in POS among 12- to 16-year-old Flemish (Belgian) adolescents.

Methods

Study area

The study took place in Ghent, the capital city of the province of East Flanders (Belgium). Belgium is ranked 22th in the Human Development index developed by the United Nations, with a value of 0.90 (maximum score = 1) [46]. Ghent comprises an area of 156.18 km^2 and has 253,266 inhabitants (population density: 1622 inh/km^2) [47, 48]. Ghent is a modern city that was founded in the eighth century at the confluence of two rivers and has a densely built historical inner city surrounded with nineteenth and twentieth century workers districts. The north of the city comprises an international harbour, whilst the south is characterised by the new train station [49].

In Ghent, the unemployment rate is 12.5, 2.0% of the population is entitled to a living wage and 18.8% is part of an ethnic-cultural minority whilst the remaining 81.2% is predominantly white [50–52]. In total, 37.0% of the inhabitants of Ghent have access to public green space (< 1 ha) within 150 m of their home and 41.9% has access to public green space (> 1 ha) within 400 m from their home [50]. Additionally, 1.8 km^2 of the city is designated to playgrounds, woods or parks where people are allowed to play [50].

Four of the participating schools were located in the city centre whilst two were located in the outskirts of the city (Fig. 1).

Participant and school recruitment

Participants (12- to 16-year-old) were recruited through schools. Before recruitment, the study design and purpose were presented in a meeting with all principals of the governmental schools located in Ghent (Flanders, Belgium). Six out of twelve schools were willing to participate. In each school at least two classes in the first to fourth grade (12- to 16-year-old) were selected by the principal or a staff member and all students from these classes were invited to participate (total of 18 classes: Additional file 1: Table S1). Participation in the study was voluntary and participants received a movie ticket as an incentive after measurements were finished.

Study protocol

Data were collected from September to December 2015 (mean daily rainfall = 0.4 mm/day, mean daily hours of sunshine: 4.1 h/day, mean maximum temperature: 15.1 °C/day). Participating schools were visited three times by the research team. Before school visits took place, all schools were asked to distribute a parental information and consent form to all parents of students in participating classes. Parents who did not give permission for their children to participate, had to sign the parental consent form and their children could hand in these parental consent forms to the researchers at the first school visit. During the first school visit, participants were asked to read and sign a participant consent form. This approach was used because adolescents had to fill in a questionnaire on a non-sensitive topic [53, 54]. This consent procedure and the research protocol for minors were approved by the medical ethics committee of the University Hospital of Ghent University (2015/0317) referring to the privacy act of December 8th, 2012 on the protection of privacy in relation to the processing of personal data [55]. Participants received a personal ID number they could use to anonymously complete a questionnaire concerning demographics. Every participant received an accelerometer, GPS device and charger for the GPS device. The participants were given verbal

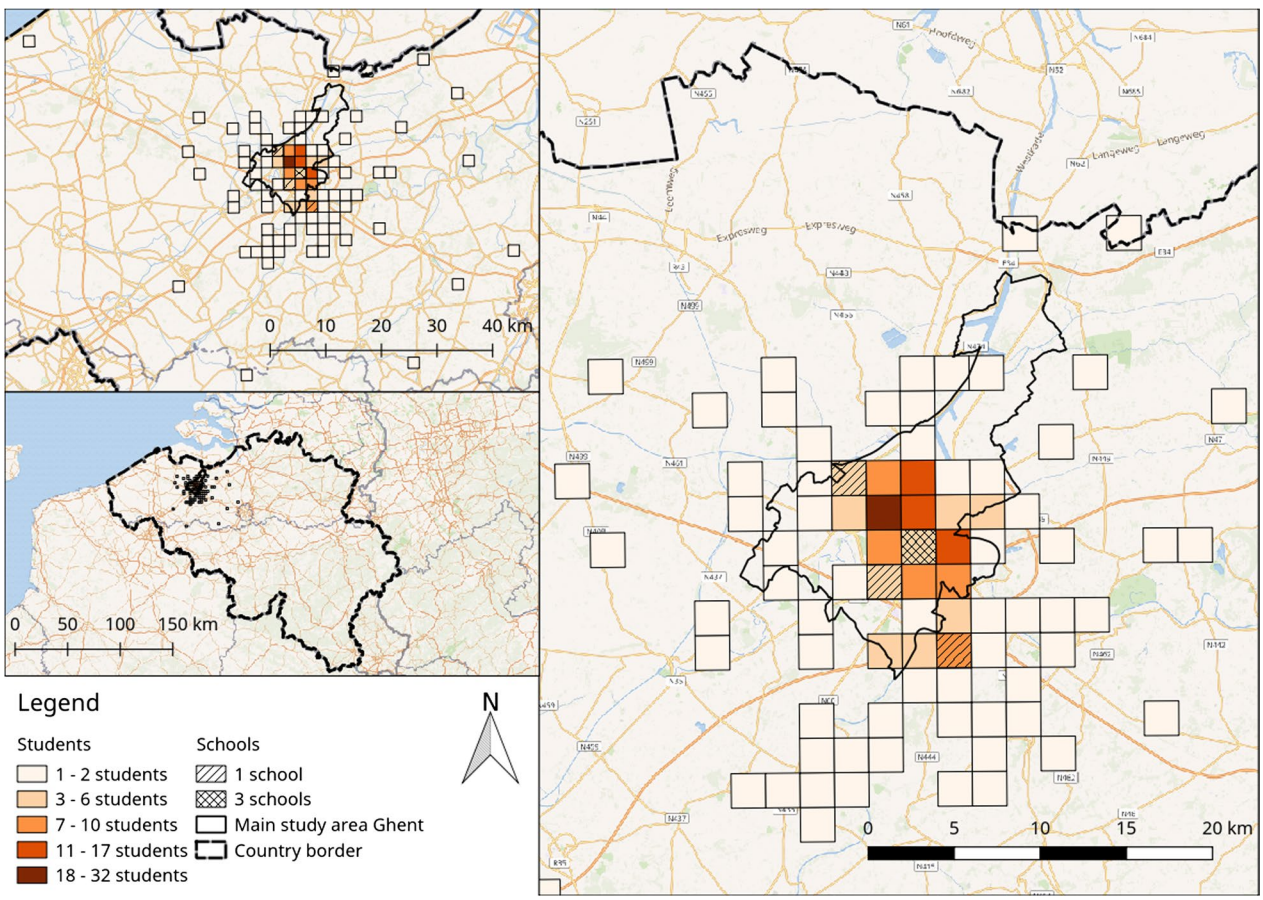

Fig. 1 City of Ghent with location of the schools and home addresses of the participants

and written instructions on how and when to wear the devices and how to charge the GPS overnight. All participants were asked for their phone number and those willing to give their number (n = 140; 49.5%), received two text messages daily: every morning to remind them to wear the devices and every evening to remind them to charge the GPS device.

After 4–5 days the devices were collected during the second school visit and the GPS and accelerometer data were downloaded from the devices. A web application was created to visualize the data from each participant on a map for each day the devices were worn.

The third school visit comprised a one-on-one interview of 10–20 min during which the personal maps were used. During this interview, participants were asked about the reasons, activities and company in POS locations that were used. An overview of the data collection process is presented in Fig. 2.

Measurements

Questionnaire

All participants were asked to complete a questionnaire that included the following questions on demographics: date of birth, place of birth, sex, address (address was used to define area of residence: rural < 300 inh/km^2, suburban: 300–600 inh/km^2, urban > 600 inh/km^2 [56]), education (general, technical, vocational or arts), school grade (first to fourth year), nationality of parents, highest education of the parents (primary education, secondary education, higher education-non university, higher education-university, I don't know [57]) and sport club membership (yes/no). Based on parental educational level, low SES was defined as: none of the parents possessed a higher education diploma whereas high SES was defined as: at least one parent possessed a higher education diploma. Based on the place of birth of the participant and the parents, a non-western-European ethnicity was defined as having at least one parent born outside of the EU15 as defined by the Flemish government [58].

Physical activity measurement

Physical activity was measured with ActiGraph GTX-3 devices which were worn during waking hours for 4–5 consecutive days on a belt on the right hip. The Actigraph GTX-3 is a reliable and valid instrument to measure physical activity in youth and adults [59–61]. The Actigraph accelerometer uses a piezoelectric acceleration sensor, that, when it undergoes an acceleration, produces a voltage signal that is expressed as 'counts' [62]. These counts were averaged in periods (called epochs) of 15 s, as recommended [63]. The counts were stored onto the accelerometer device and later on downloaded using Actilife software version 6. For each 15 s epoch, the activity level [sedentary time (e.g., watching TV while sitting down), light-intensity physical activity (LPA) (e.g., walking slowly), moderate-intensity physical activity (MPA) (e.g., walking at 7.2 km/h) and vigorous-intensity physical activity (VPA) (e.g., running) [64–66]) was determined using Evenson cutpoints (sedentary time $\leq$ 100; LPA > 100, < 2296; 2296 $\geq$ MPA < 4012, VPA $\geq$ 4012) [67]. Continuous periods of 60 min of zero values were classified as non-wear time and removed from the data. Only participants with at least 1 day with at least 9 h of valid data were included in the analysis [32, 68]. Thus, when GPS devices were turned off for a substantial amount of time, this could have led to that day being excluded from analysis.

Spatial measurements: locations

A GPS device (Qstarz BT-Q1000XT) was worn on a belt on the left hip to track the locations of the participants. The devices were configured and data downloaded using the program Q-travel. Data were logged every 30 s. Epochs of 30 s have been used successfully for GPS data processing in previous studies with adolescents [69, 70]. Additionally, Schipperijn et al. [71] showed that limited differences exist between GPS data stored at epochs of 5, 15 and 30 s and that the three data collection epochs had the same median error.

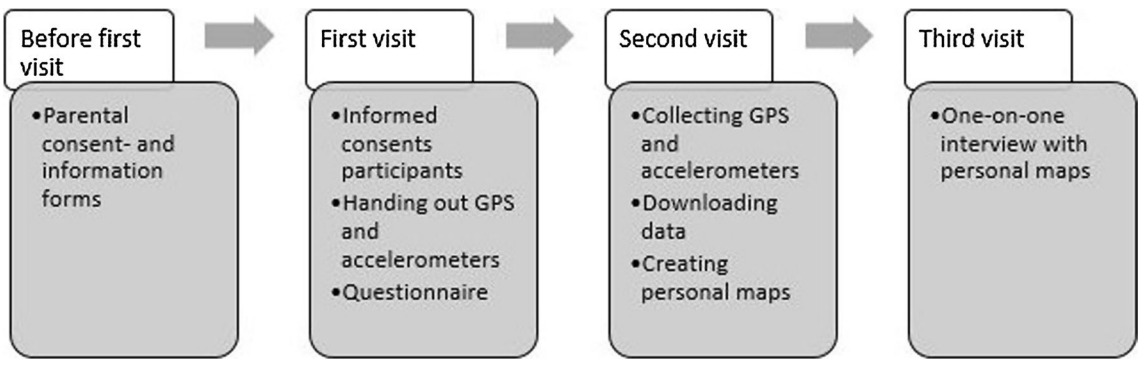

Fig. 2 Data collection process

One-on-one interview with personal maps

The data from the GPS devices were stored in a PostgreSQL database with PostGIS in order to visualize the visited locations of each participant in the self-made web application. The personal ID was used to log each participant in a self-made web application, where an individual map was available for each day the participant wore the devices (Fig. 3). On this individual web based map, the trip of the participant was visualized by placing a dot on the map every 30 s. Additionally, a light to dark colour scheme was used, to give an indication of the time during the day. The exact time of a point could be seen by clicking on a point. It was possible to zoom in on the map, which gave a clear overview of the locations that were visited. By using OpenStreetMap as a background layer, contextual information on the visited places of the participant could be gathered. The first week- and weekend day with complete data were selected (excluding the day the devices were handed out) and discussed with the participants. When no weekdays with complete data were available, two weekend days were selected and vice versa. For participants with only 1 day with complete data, this day was selected. For these selected days, the participants had to indicate the type of each location (e.g., school, home, a park, train station) they visited. For the locations that were classified as outdoor POS (street, shopping street/mall, square, park, outdoor sports ground/playground, parking lot, vacant lot and public transportation stop/station) three additional questions were asked: "who accompanied you here?"; "which activities did you engage in?"; "why did you choose this place?".

The colours of the dots represent the time course of the day: every 30 s a dot was placed on the map (Temporal resolution: 30 s). Lighter colours represent the start of the day, darker colours represent the end of the day. The green arrow represents the first data point registered by the GPS and the "finish flag" represents the last registered data point by the GPS.

Data processing

An overview of the data processing can be found in Fig. 4. First, all GPS and accelerometer data were created as CSV (comma separated value) files and imported into the Personal Activity and Location Measurement System (PALMS©) which was developed by the Centre for Wireless and Population Health Systems, University of California, San Diego.

Secondly, PALMS was used to merge all corresponding GPS and accelerometer data points (i.e. all data points-in epochs of 30 s-were matched according to the timestamp). PALMS identified speeds above 130 km/h, changes in distance higher than 1 km and elevations higher than 100 m between two data points (that are 30 s apart) as invalid data. In PALMS every data point (i.e. corresponding with an epoch of 30 s) was categorized into either an event or a transport related data point according to the acceleration measured. The transport related data points were further categorized into pedestrian ($\geq$ 1 km/h < 10 km/h), bicycle ($\geq$ 10 km/h, < 25 km/h) or motorized transport ($\geq$ 25 km/h) [72] (data not reported). All data points that were not identified as transport, were categorized as an event. Additionally, all

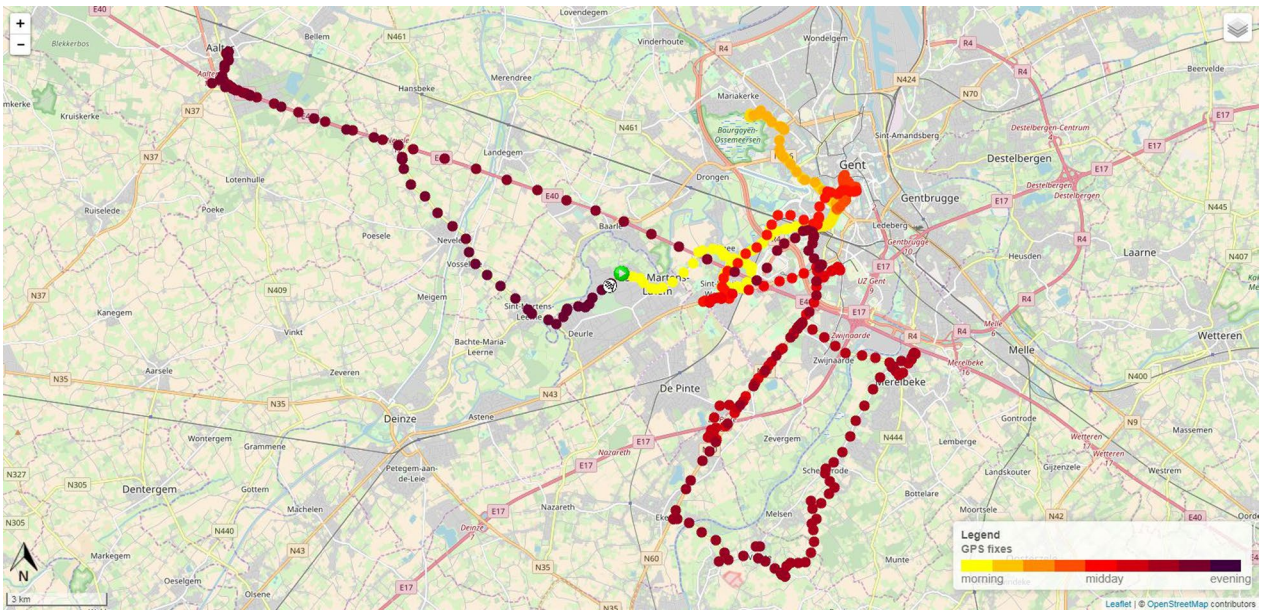

Fig. 3 Example of a personal map

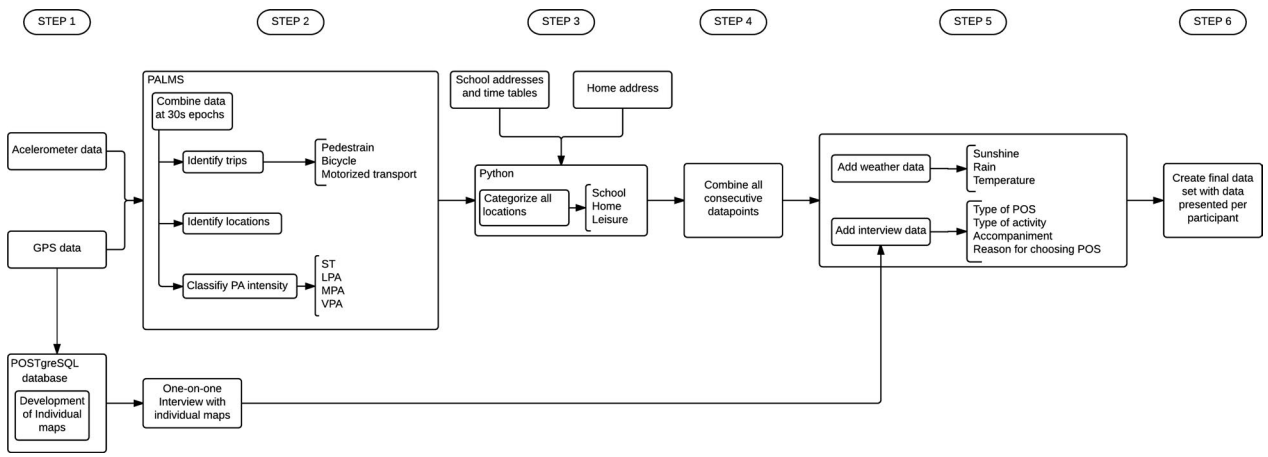

Fig. 4 Data processing. *GPS* global positioning system, physical activity = physical activity, sedentary time = sedentary time, *LPA* light-intensity physical activity, *MPA* moderate-intensity physical activity, *VPA* vigorous-intensity physical activity, *POS* public open space

epochs were classified according to the physical activity intensity using Evenson cutpoints [67].

Thirdly, the PALMS dataset was combined with information on the home and school addresses and school time tables in Python. All data points that were identified as an event (i.e. not a trip) were categorized into three domains: school, home or leisure. The data were categorized in the domain school during school hours, when the participant was located at school (100 m buffer). Within the domain school, a distinction was made between physical education classes, other classes and recess based on the time tables of the participating classes. The home domain was defined as being at the home address with a 100 m buffer around the home. All other data were categorized in the leisure domain. A similar approach was used in previous Danish research [68].

Fourth, all consecutive data points allocated to the same domain were combined, resulting in a database with data per trip and event.

In the fifth step, all data from the individual interviews (i.e. for each POS location, the accompaniment, reason why they chose that POS and activities performed) and weather data (mean min sun/day, mean mm rain/day and average temperature/day) were added to the database. All trips or locations misclassified by PALMS were corrected using the interview data (e.g., when a participant indicated that a certain trip was done by bus, however, due to traffic congestion the speed was rather low (< 25 km/h) and this trip was falsely allocated to the bicycle category by PALMS, this was picked up during the interviews and corrected).

In order to perform the analyses, the data had to be presented per participant (instead of per event, as was the case after step five). Therefore, in the final data processing step, data were extracted from the data file created in step five, in order to create a new data file with data per participant. New variables were created with following information: mean wear time; mean number of POS visits accompanied by friends/classmates, siblings/cousins, parents/grandparents, organisation or alone; average sedentary time/day, in LPA/day, MVPA/day and VPA/day in total, located in POS (inclusive LPA, MVPA and VPA accumulated during trips to and from POS).

In this study, only time spent in the "leisure" category in POS and transportation to and from a POS was included. In other words, when a participant went to a park by bike, the time on the bike and the time spent in the park was included in the analyses. However, when a participant went to school by bike and cycled through a park, this trip was not included as this was categorized as a trip to school (and not POS) using active transportation.

Data analysis

Descriptive statistics were calculated using IBM SPSS statistics 22 software. Chi^2 tests and independent sample *t* tests were performed in SPSS to calculate differences between included and excluded participants (based on valid data).

Associations of individual factors (i.e. age, gender, ethnicity, education and sport club membership) and social environmental factors (accompaniment in POS with friends/classmates, siblings/cousins, parents/grandparents, organisation or alone) with the outcome measures (time, sedentary time, LPA, MVPA and VPA in POS, inclusive trips to and from POS) were examined using Multilevel Hurdle models and Gamma models (level 1 = subject, level 2 = school) using the package lme4 [73] in R version 3.4.1.

Different statistical models were used for the different outcomes as data were distributed differently. The outcome 'time spent in POS', was positively skewed and contained a high number of zeros (i.e. when a participant did not use a POS) demanding a multilevel hurdle model. A hurdle model includes two parts, first associations between the independent variables and the odds of having visited a POS were estimated by means of logistic regression analysis (binomial variance and logit link function) among all participants (n = 173). Second, a multilevel regression model with gamma variance and log link function was used to estimate the associations between the independent variables and the amount of time that was spent in POS among the participants who had used a POS (n = 130). The exponentiated regression coefficients represent the proportional difference in min spent in POS with a one-unit difference in the independent variables.

For the outcomes sedentary time, LPA, MVPA and VPA in POS, only the participants who had used a POS during data collection (n = 130) were included. This was done because participants who did not use a POS, logically also did not engage in any sedentary time, LPA, MVPA or VPA in POS. The outcomes 'sedentary time in POS', 'LPA in POS' and 'MVPA in POS', were skewed but did not contain many zeros and, therefore, multilevel regression models with gamma variance and log link function (selected based on Akaike's Information Criterion) were fitted. These models estimate the association between the independent variables and the amount of time spent in sedentary time, LPA and MVPA in POS among the participants who had used a POS for sedentary time, LPA and MVPA. For the outcome VPA, a multilevel hurdle model was selected as data were skewed and contained a high number of zeros.

A stepwise procedure was used to build the models. First, all potential covariates (residence-urban, suburban or rural-, mean wear time, mean POS visits/day, number of days with valid data, rain, sun, temperature, total time in POS, mean min sedentary time/day for outcome sedentary time in POS, mean min LPA/day for outcome LPA in POS, mean min MVPA/day for outcome MVPA in POS and mean min VPA/day for outcome VPA in POS) were entered simultaneously into a model to identify those that were significantly related to the outcomes. Based on this, residence, temperature, mean wear time, mean POS visits/day, and number of days with data were included as covariates in all subsequent analyses. Mean min LPA/day, MVPA/day and VPA/day were included as covariates in the analyses with the outcome variables LPA, MVPA and VPA in POS, respectively, and total time in POS was included as a covariate in the analyses with the outcome variables sedentary time, LPA, MVPA and VPA in POS. Second, all individual factors (i.e. age, gender, ethnicity, education and sport club membership) were entered separately into a model adjusted for the appropriate covariates (see above).

Third, all individual factors that were significantly related to the outcome in the previous step were entered together into one model, again adjusting for the relevant covariates.

In a fourth step, each social environmental variable was entered separately into a model adjusting for the significant individual factors identified in step 2 and the relevant covariates. These four steps were performed separately for each outcome variable.

POS visitation in the company of an organisation was not included in the analyses, as only 2.5% of all POS visits were done in the company of an organisation. It was not possible to analyse associations between the environmental factors (i.e. location: street, shopping street/mall, square, park, outdoor sports ground/playground, parking lot, vacant lot and public transportation station/stop) and the outcome variables (SB, LPA, MVPA, VPA), because more than 70% of all POS visits were located at a public transportation stop/station. Level of significance was set at $\alpha = 0.05$.

Results

Descriptive statistics

In total, 283 adolescents were invited to participate in the study of which ten had no consent from their parents or were not willing to participate themselves. Of the remaining 273 participants, 100 were excluded from the analyses. Reasons for exclusion were: absence when handing out material or during interview (n = 49), no days with valid data for at least 9 h (n = 22), being older than 16 years (n = 12), forgot to wear material (n = 7), no longer enrolled at this school/class (n = 4), material forgotten at home (n = 3) or the GPS did not work properly (n = 3). Eventually, 173 participants aged 12–16 years were willing to participate, had parental consent and valid data for at least 1 day (Fig. 5).

No differences were found for gender, SES and ethnicity between the participants who were included for analysis (n = 173) and those who were excluded (n = 100) ($p > 0.05$). The excluded participants were significantly older than the included participants (15.6 vs. 14.2; $p < 0.05$) because participants older than 16 years were excluded from analyses.

The sample had a mean age of 14.2 ± 1.1 years, consisted of 54.4% girls and 93.1% was living in an urban or suburban environment. Most participants were enrolled in general education (68.8%), 28.3% had a non-western-European ethnicity and 22.5% had a lower SES based on parental educational level. Almost 60% of

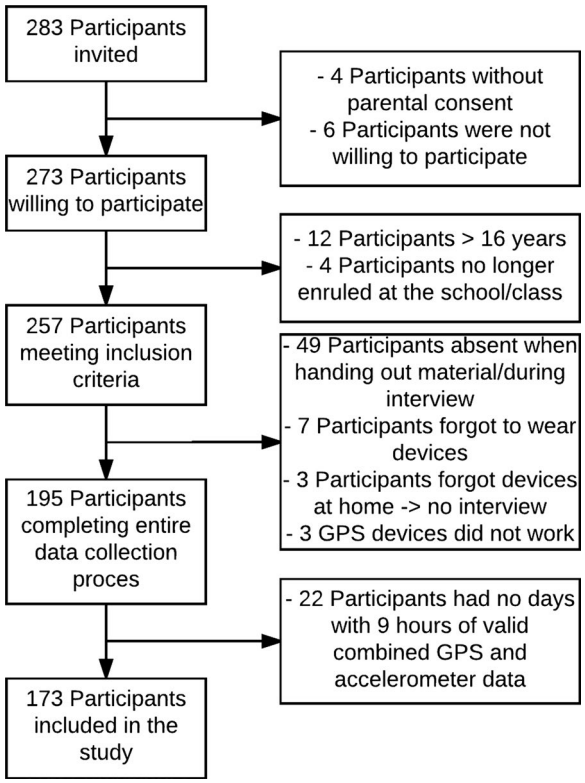

Fig. 5 Sampling of the participants

Table 1 Descriptive characteristics of the sample (n = 173)

Age (mean ± SD)	14.2 ± 1.1
Gender (% girls)	54.4
Living environment (%)	
Rural	6.9
Sub-urban	16.8
Urban	76.3
Education (%)	
General	68.8
Vocational	22.0
Technical	9.2
Other ethnicity (%)	28.3
Lower SES (%)	22.5
Sport club membership (%)	58.0
Sedentary time (mean h/day ± SD)	8.8 ± 1.6
LPA (mean h/day ± SD	3.3 ± 1.0
MVPA (median min/day; Q1, Q3)	36.5; 22.9, 51.4
% of participants who used a POS	75.1
Mean number of POS visits among participants who used a POS	1.83 ± 1.2

Skewed data were reported as median and interquartile range

SD standard deviation, *SES* socio-economic status, *MVPA* moderate- to vigorous-intensity physical activity, *Q1* 25th percentile, *Q3* 75th percentile, *min* minutes, *POS* public open space

the participants were member of a sport club and the median min of MVPA/day was 36.5. Among the participants who used a POS (75.1% of the participants), the mean number of POS visits per day was 1.8 ± 1.2 (Table 1).

All participants with one (n = 63) or 2 days (n = 110) of complete GPS and accelerometer data for 9 h minimum/day were included in the study. During the 283 included days 373 events took place at an outdoor POS. Participants reported that more than half of the POS visits were done in the company of a friend/classmate (59.8%) and most POS visits were located at a public transportation stop/station (71.0%). The most frequently mentioned reasons to visit a specific POS were: to wait for something/someone here (e.g., train) (30.3%), because friends/classmates/siblings/cousins wanted to go to that POS (17.4%), for 'other reasons' (e.g., for shopping purposes, easy to meet up) (17.4%) or because the POS was close to school or their home (13.8%). Standing was most frequently reported by the participants as the main activity in POS during a POS visit (43.1%), followed by walking (38.5%) and sitting or lying down (13.8%). The one-on-one interviews revealed that participants often indicated to 'just hang around' in POS while talking to friends (Table 2).

Associations of individual factors and company with time spent in pos

The logistic regression model shows that the odds for having used a POS were 2.20 times higher for participants with a non-western-European ethnicity compared to participants with a western-European ethnicity and 8.09 times higher for participants enrolled in technical education compared to participants enrolled in general education (both trends towards significance, see Table 3). In the multivariate model (data not shown in table), education became significant (OR: 8.68; 95% CI 1.03–72.75) while ethnicity remained borderline significant (OR: 2.33; 95% CI 0.93–5.86). For the participants who had visited a POS at least once during the days that were measured, results showed that with each additional visit accompanied by siblings, on average 60% more time was spent in POS per day (Exp. B: 1.60; 95% CI 1.26–2.04; data not shown in table). In other words, the higher the number of POS visits with siblings, the higher the total time spent in POS daily.

Associations of individual factors and company with sedentary time and physical activity in pos

None of the individual and social environmental factors was significantly associated with sedentary time and LPA in POS (see Table 4). The analyses for the outcome

Table 2 Descriptive characteristics of POS visits (n = 373)

Company (% of POS visits; multiple answers possible)	% (n = 373)
Friends/classmates	59.8
Siblings/cousins	16.4
Parents/grandparents	16.4
Alone	15.6
Organisation	2.5
Location (% of POS visits)	
Public transportation stop/station	71.0
Street	9.4
Parking lot	5.4
Square	3.5
Shopping street	3.2
Sport field/playground	2.9
Park	2.9
Shopping mall	1.3
Vacant lot	0.3
Reasons for POS visit (% of POS visits; multiple answers possible)	
I had to wait for something/someone here (e.g., train)	30.3
My friends/classmates/siblings/cousins wanted go there	17.4
Other (e.g., for shopping purposes, easy to meet up)	17.4
This POS is close to my home/school	13.8
I was going somewhere else and decided to stay there	10.1
It is a habit to go there	8.3
There is a nice atmosphere	4.6
My parent want me to go there/I am not allowed to go anywhere else	4.6
There is sport infrastructure available	4.6
This POS is easy accessible	3.7
I know this place for a long time and I am familiar with this POS	1.8
Activity in POS (self-reported; multiple answers possible)	
Standing	43.1
Walking	38.5
Sitting/lying down	13.8
Ball sports	6.4
Biking	2.8
Other	1.8
Skateboarding/BMX/roller-skating	0.9
Active games	0.9
Jogging	0.9

POS public open space

Table 3 Associations between individual factors and time spent in POS

Individual factors	Logistic regression[a]		Gamma model[b]	
	OR	95% CI	Exp. B	95% CI
Gender (ref = male)	1.82	0.88–3.79	0.98	0.69–1.38
Education (ref = general)				
Vocational	1.09	0.41–2.88	1.42	0.65–3.11
Technical	8.09°	0.97–67.62	1.15	0.61–2.15
Age	1.00	0.70–1.43	1.05	0.88–1.26
Ethnicity (ref = Belgium)	2.20°	1.88–5.49	1.25	0.84–1.86
Sport club membership (ref = yes)	1.80	0.85–3.85	1.21	0.87–1.68

OR odds ratio, *CI* confidence interval, *Exp. B* exponent of B, *POS* public open space, *ref* reference category, *min* minutes, ° $\alpha < 0.1$ = trend towards significance

[a] The logistic regression model estimated the association of the independent factors with the odds of having visited a POS

[b] The Gamma models (Exp. B) estimated the proportional difference in min spent in POS associated with a one-unit difference in the independent variables for adolescents that had visited a POS. Analyses were controlled for mean temperature, residence, POS visits/day, total wear time (mean min/day), and amount of days. All Gamma models were fitted using the log link function

MVPA in POS revealed that among the participants who had used a POS, girls engaged on average in 43% less min of MVPA/day in POS compared to boys. None of the other individual or social environmental factors were significantly associated with MVPA in POS.

The logistic regression model for the outcome VPA in POS shows that girls had a 79% lower odds of having used a POS for VPA compared to boys and an increase in age with 1 year was associated with a 40% lower odds of having engaged in VPA in POS (trend towards significance for age, see Table 5). When gender (OR: 0.16; 95% CI 0.05–0.52) and age (OR: 0.52; 95% CI 0.30–0.93) were entered simultaneously into a model, both were significant (data not shown in table). Among those who had used a POS for VPA, girls engaged on average in 40% less min of VPA in POS/day compared to boys and participants enrolled in vocational education spent on average 41% less min in VPA in POS/day compared to participants enrolled in general education (trend towards significance for education). When gender and education were entered in the multivariable gamma model, only gender remained significant (Exp B: 0.63; 95% CI 0.41–0.98).

Discussion

In this study, a socio-ecological approach was used to gain insight into the prevalence, frequency and context (i.e. company, locations and reason) of POS visitation and the factors associated with time, sedentary time and physical activity in POS among adolescents. Our study revealed that 75% of the participants used a POS and during most POS visits, participants were accompanied by friends/classmates. Mainly public transportation stops/stations were used, and subsequently the most reported reason for POS visitation was "to wait for something/someone (e.g., bus)". Furthermore, ethnicity, education, gender and age were the individual factors associated with at least one outcome. The only social environmental

Table 4 Associations between individual and social environmental factors with sedentary time, LPA and MVPA spent in POS

Individual factors	Gamma model sedentary time		Gamma model LPA		Gamma model MVPA	
	Exp. B	95% CI	Exp. B	95% CI	Exp. B	95% CI
Gender (ref = male)	0.89	0.63–1.27	0.73	0.53–1.00	0.57**	0.41–0.80
Education (ref = general)						
Vocational	1.43	0.85–2.40	0.71	0.42–1.19	0.74	0.44–1.24
Technical	1.11	0.62–2.00	0.93	0.51–1.67	0.72	0.40–1.29
Age	1.08	0.91–1.29	0.98	0.82–1.16	0.96	0.80–1.15
Ethnicity (ref = Belgium)	1.12	0.78–1.61	1.09	0.74–1.60	0.96	0.64–1.42
Sport club membership (ref = yes)	0.94	0.66–1.36	0.75	0.52–1.09	0.83	0.57–1.19

The Gamma models (Exp. B) estimated the proportional difference in sedentary time, LPA and MVPA in POS associated with a one-unit difference in the independent variables for adolescents that had used a POS. Analyses were controlled for mean temperature, residence, POS visits/day, total wear time (mean min/day), total time in POS and amount of days. All Gamma models were fitted using the log link function

LPA light-intensity physical activity, *MVPA* moderate- to vigorous-intensity physical activity, *OR* odds ratio, *CI* confidence interval, *Exp. B* exponent of B, *POS* public open space, *ref* reference category, *min* minutes, ° = α < 0.1 = trend towards significance

**α < 0.01

Table 5 Associations between individual and social environmental factors with VPA in POS

Individual factors	Logistic regression[a]		Gamma model[b]	
	OR	95% CI	Exp. B	95% CI
Gender (ref = male)	0.21**	0.07–0.63	0.60*	0.39–0.92
Education (ref = general)				
Vocational	0.70	0.17–2.90	0.59°	0.34–1.04
Technical	0.32	0.07–1.52	1.15	0.48–2.75
Age	0.60°	0.36–1.00	0.94	0.73–1.19
Ethnicity (ref = Belgium)	0.71	0.25–2.00	0.84	0.53–1.37
Sport club membership (ref = yes)	0.54	0.19–1.59	1.18	0.74–1.88

VPA vigorous-intensity physical activity, *OR* odds ratio, *CI* confidence interval, *Exp. B* exponent of B, *POS* public open space, *ref* reference category, *min* minutes, ° = α < 0.1 = trend towards significance

*α < 0.05; **α < 0.01

[a] The logistic regression model estimated the association of the independent factors with the odds of having used a POS for VPA

[b] The Gamma models (Exp. B) estimated the proportional difference in min of VPA in POS associated with a one-unit difference in the independent variables for adolescents that had used a POS. Analyses were controlled for mean temperature, residence, POS visits/day, total wear time (mean min/day), total time in POS, total time in VPA/day and amount of days. All Gamma models were fitted using the log link function

variable associated with time spent in POS was accompaniment by siblings.

Surprisingly, there was limited variability in the POS locations used by the participants in this study as 70% of all POS visits were located at a public transportation stop/station. This suggests that public transportation stops/stations are frequently visited by adolescents in Flanders (Belgium), but these locations are not very suitable for physical activity. POS such as parks, a playground/sport field and squares are very suitable for physical activity, but were not often used by adolescents. Only 3.5% of the POS events was located at a square, 2.9% at a sport field/playground and 2.9% in a park. However, when the POS visits that took place at a public transportation stop/station are not taken into account, 12.0% of POS visits were located at squares; 10.3% at sport fields/playgrounds and 10.2% at parks. These findings are of importance for interventions aiming at the promotion of POS use among adolescents in Flanders, as we now know that POS such as parks, sport fields/playgrounds and squares are not often used and extra initiatives are warranted to encourage their use. Additionally, when public transportation routes are (re)designed, it is recommended to place public transportations stops close to locations suitable for physical activity (such as a park of square). Our results differ from previous Danish research where GPS measures revealed that 40% of the adolescents had used a playground, 97% had used urban green space and 32% had visited a shopping centre at 1 day during the data collection period [68]. It is difficult to compare the results of our study with these of this Danish study as the results are presented differently (i.e. % of events located at specific location, compared to % of participants that used a location), however, clearly some differences exist. On the one hand, some methodological differences between the studies could have caused these differences. In the Danish study, GIS was used to categorize the events into subdomains (i.e. locations such as playgrounds or urban green space) used during leisure time. It has been acknowledged that sometimes GIS layers lack details [45] which could have led to misclassification of events. For example, when a participant was waiting at the bus stop near a park, this could have been misclassified as an

event in the park. Additionally, in the Danish study, the subdomain "public transportation stop/station" was not included, and 1–4 days of data were included whereas in our study only 1–2 days. On the other hand, these differences between studies could possibly be attributed to cultural differences between countries meaning that POS use is more integrated in Danish adolescents' life [68].

This study provided new insight into the associations between the accompaniment and time, sedentary time and physical activity in POS. Results from the one-on-one interviews revealed that adolescents used POS most often with friends/classmates, followed by siblings, parents and alone. Previous research using ecological momentary assessment indicated that most 14-year-old adolescents reported to be physically active in the company of friends, followed by classmates and family members. Furthermore, the company with whom the greatest proportion of walking occurred was with friends or alone [74, 75]. In this study, only the accompaniment with siblings was associated with more time in POS, whereas no associations were found between the accompaniment and physical activity in POS. These contradicting results indicate that additional research on this topic is needed and that interventions targeting all children within a family could possibly be more effective. One explanation for this result could be that adolescents are allowed to stay longer outside when their parents know they are not alone, but in the company of a sibling.

It is known that total physical activity levels decline when adolescents grow older [76–78]. This study has added upon this knowledge by demonstrating that this age-dependent decrease also exist for POS physical activity. In this study, an increase in age with 1 year, was associated with a 40% lower odds of having engaged in VPA in POS. From previous qualitative research it became apparent that the playgrounds and facilities present in POS are often designed for younger children causing a lack of age appropriate facilities for (older) adolescents [27]. Creating POS with attractive facilities for older adolescents (such as sport fields [27] and adventurous playgrounds with high swings and big slides [79]) could possibly counteract this age-dependent decline in physical activity levels.

Total physical activity levels among adolescent girls have been shown to be lower than adolescent boys' physical activity levels [77, 78, 80]. Additionally, our results revealed that also in POS, girls accumulate less physical activity compared to boys. Analyses revealed that boys spent more time in MVPA and VPA in POS compared to girls. This is in line with previous research from the US using GPS and accelerometers in a sample of 11- to 14-year-olds. It was reported that more physical activity was accumulated at playgrounds by boys compared to girls and boys had higher odds of spending time in MVPA at parks compared to girls [30]. Furthermore, previous observational research reported lower use of parks by girls (children and adolescents) and lower energy expenditure levels among girls compared to boys [26, 34, 81, 82]. Additionally, previous studies have shown that safety related factors (such as the presence of sufficient lighting [83], traffic safety [84], number of violent crimes [85]) were related to physical activity in parks and in the neighbourhood among girls. It is thus possible that safety issues contribute to gender differences in POS use. However, safety related factors are very context-specific and can differ between countries. In Belgium, the overall victimisation rate (= percentage of people victimised once or more) was significantly higher than the average of the 18 EU countries in 2004 [86].

Additionally, these results suggest that urban planners should consider adding attractive characteristics and features, in order to attract more girls to POS. It has been shown that adolescent girls prefer individual, non-competitive activities such as dancing or running or group activities with the focus on fun, such as netball [87–89]. Including features suitable for such activities could be a useful strategy to attract more girls to POS. However, additional research is needed to define what POS characteristics could specifically attract or repel girls for physical activity in POS.

Our study revealed ethnicity to be associated with time spent in POS among adolescents. The odds for having used a POS was higher among non-western-European adolescents compared to participants with a western-European ethnicity. However, it could be possible that adolescents with non-western-European ethnicity used public transportation more often, which could have influenced our results (because of the high number of POS visits that were located at public transportations stops/stations). This is an important result, as adolescents with a non-western-European ethnicity are often hard to reach for interventions. However, our results were only borderline significant and research on this topic among adolescents is lacking and, therefore, these results should be interpreted with caution.

Furthermore, this study revealed that participants enrolled in technical education were more likely to spent time in POS and participants enrolled in vocational education spent less min in VPA in POS compared to participants enrolled in general education. In Flanders (Belgium) technical education is focussed on practice lessons and technical-theoretical courses, whereas vocational education is focussed on learning a profession [90]. Not much is known about the association between education and time in POS among adolescents, but our findings are consistent with previous Australian research on

adults' individual factors associated with park use. This Australian study revealed that park users had less educational qualifications compared to non-park users [91]. However, adolescents enrolled in vocational education accumulated less min of VPA in POS compared to participants enrolled in general education. Currently, it is not known which POS characteristics invite adolescents to engage in VPA in POS and it is possible that differences exist according to educational level. Another explanation could be that adolescents enrolled in vocational education visit other types of POS what are less inviting for VPA (such as a train station). These findings have important social relevance as people with low educational level and low SES are at risk for low levels of physical activity [92] and are target populations that are hard to reach by standard physical activity initiatives from sport clubs or school sport. Therefore, interventions taking place in POS could have the ability to reach the target groups most in need for physical activity promotion. However, additional research is needed to define how adolescents could be encouraged to engage in physical activity in POS.

To our knowledge, this was the first study to look into the associations with sedentary time in POS. However, no associations were found with the individual nor with the social environmental factors. This could indicate that other factors are more important for sedentary time in POS. In this study, no environmental factors were included in the analyses, however, it is possible that the environmental characteristics of a POS (e.g., the presence of benches), are associated with sedentary time in POS. These factors should be included in future research.

This study emphasized the need for further research into the factors associated with time, sedentary time and physical activity in POS among adolescents. Within this study a social ecological approach was pursued. However, due to lacking variability in the POS locations that were used it was not possible to study the associations for the different types of POS locations that were used with time, sedentary time and physical activity in POS. Future studies could prevent this issue by assessing a larger sample from different cities and gathering data on more than 2 days. For larger samples, using data collected by the participants' smartphones using mobile object trajectory analysis, could be a cost-effective and time-efficient option. Furthermore, it is recommended to develop a method in which subjective measurements can be obtained in a less time consuming manner. For example, using ecological momentary assessment via a smartphone application in combination with GPS and accelerometers could be a useful method [93]. Such an application can prompt questions about the accompaniment or about the characteristics of the public open space, when the smartphone detects that a participant is present at a public open space of interest. This way the use of a smartphone application could lessen the burden on the researchers and allow the researcher to collect data on more than 2 days. However, developing such an application poses some technical difficulties and is very expensive. In this study, no specific spatial analyses were performed such as spatial clustering or spatial time services. We suggest including such analyses in future research as these were outside the scope of this paper.

Strengths and limitations

One of the major strengths of this study was the use of objective measurement methods for both locations and physical activity measures. By using these methods it was possible to investigate the locations that were actually used by the adolescents. Furthermore, these objectively measured data were combined with subjective interview data, to provide conclusive data and avoid the weaknesses of using solely qualitative or quantitative measurement methods [94]. Another strength was the broad definition of POS that was used in this study, whereas in other research often narrow definitions of POS were used. For example Edwards defined POS as "spaces reserved for the provision of green space and natural environments, accessible to the general public free of charge" and thereby excluded all non-green POS [95]. In this study, sedentary time and physical activity accumulated during trips to and from POS were included in analyses which, to our knowledge, has never been done before and provides a more comprehensive view on POS' contribution to sedentary time and physical activity compared to previous studies that only included sedentary time and physical activity accumulated after arriving at the POS. Furthermore, it was attempted to include factors associated with POS use from different layers of the socio-ecological model in order to provide a more comprehensive insight into the use of POS. However, only individual and social environmental factors could be included into the analyses, because of the low levels of POS use and the low variability in POS locations that were used. This could be due to the fact that only 1 or 2 days of data were included for analyses, which was the biggest limitation of this study. Furthermore, also events that were more "transport" related (e.g., when participants were waiting for a bus at a bus stop, with the sole intention to take the bus) were included in our study and this could be considered as a limitation. Due to the structure of the data it was not possible to solely select the events located at a public transportation stop/station that could actually be classified as leisure time (e.g., when participants used a station as a meeting place). It is possible that the high number of POS visits located at public transportations

stops/stations has altered the results. Another limitation of the study was that the data were collected from September to December, a period that is characterized by lower temperatures in this part of the world. This could have elicited different results compared to a period with generally better weather conditions. However, by including weather information (sun, rain and temperature) as covariates in the statistical analyses, we tried to tackle this barrier. Only three questions were included in the personal interviews and no questions were asked concerning the reasons for not engaging in physical activity. This could also be considered as a limitation of this study. The data were only collected in one city in Flanders (Belgium), inclusion of other cities could have provided different results and would have increased the generalizability of the current findings.

Conclusion

Our research showed that ethnicity, education, gender, age and accompaniment are associated with time and physical activity in POS but not with sedentary time in POS among adolescents. Identifying the population groups that are currently least using POS (for physical activity) is important in order to guide interventions. In this study it was found that boys, younger adolescents, non-western-European adolescents and lower educated adolescents used POS more often (for physical activity). Additionally, the accompaniment by siblings in POS was shown to be associated with more time spent in POS. Understanding the use of POS is necessary in order to develop POS that are attractive to all adolescents and provide opportunities to engage in physical activity alone or in company. Additional research is warranted to elaborate on the current knowledge about the use of POS among adolescents.

Additional file

Additional file 1: Table S1. Information about participating classes.

Abbreviations

BMI: body mass index; CSV: comma separated value; GIS: geographical information system; GPS: global positioning system; LPA: light-intensity physical activity; MPA: moderate-intensity physical activity; MVPA: moderate- to vigorous-intensity physical activity; PALMS: personal activity and location movement system; POS: public open spaces; SES: socio-economic status; US: United States; VPA: vigorous-intensity physical activity; WHO: World Health Organisation.

Authors' contributions

Design of the study: LVH, HV, PC, DVD, NVDW, JVC, BD; Data collection: LVH, HV, TB; Data processing, analyse and interpretation: LVH, HV, TB, JVC; Drafting the article: LVH; Critical revision of the article: LVH, HV, PC, DVD, NVDW, TB, JVC, BD; All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Parents gave passive consent and participants gave active consent. This approach was used because adolescents had to fill in a questionnaire on a non-sensitive topic [53, 54]. This consent procedure and the research protocol for minors were approved by the medical ethics committee of the University Hospital of Ghent University (2015/0317) referring to the privacy act of December 8th, 2012 on the protection of privacy in relation to the processing of personal data [55].

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CHAPTER 3

ENVIRONMENTAL CHARACTERISTICS OF PUBLIC OPEN SPACES ASSOCIATED WITH ADOLESCENTS' PUBLIC OPEN SPACE VISITATION AND PHYSICAL ACTIVITY

CHAPTER 3.1.

PUBLIC OPEN SPACE CHARACTERISTICS INFLUENCING ADOLESCENTS' USE AND PHYSICAL ACTIVITY: A SYSTEMATIC LITERATURE REVIEW OF QUALITATIVE AND QUANTITATIVE STUDIES

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ABSTRACT

The objective of this systematic review was to provide insight into the specific characteristics of public open spaces (POS) associated with adolescents' POS visitation and physical activity (PA). Qualitative research suggests many characteristics to be associated with POS visitation and PA. Quantitative evidence confirmed a positive association between presence of trails, playgrounds and specific types of sports fields (e.g. basketball) with POS visitation and PA, whereas safety and aesthetics seemed subordinate. Suggestions for future research, as well as some methodological recommendations are provided.

Keywords: teens, recreation, parks, exercise, green space, urban, youth

INTRODUCTION

The World Health Organisation (WHO) recommends adolescents engage in 60 minutes of moderate- to vigorous-intensity physical activity (MVPA) every day [1]. Such levels of physical activity (PA) enhance adolescents' health [2,3]. However, more than half of adolescents do not comply with these guidelines [4-7], and there is a rapid decline of PA levels through adolescence [8]. Insufficient PA is considered one of the leading risk factors for global mortality and negatively affects public health [7]. Moreover, it is of great importance to develop healthy PA habits at a young age, because these habits tend to track from adolescence into adulthood [9].

Socio-ecological models which have been adopted to explain PA behaviours among youth, highlight the importance of environmental characteristics in explaining PA behaviour [10]. These socio-ecological models consist of different levels which include four domains of active living; active recreation, physical activity at home, active transportation and occupational/school physical activity. Within the "active recreation"-domain, public open spaces (POS) are considered to be an important location (i.e. physical environment) where adolescents can accumulate PA [11]. POS are defined as any public space, accessible to all people, independent of age, ethnicity, physical disabilities or other characteristics. POS can be publicly or privately owned, and are freely accessible. Parks, squares and playgrounds are examples of POS hypothesized as potential key locations for adolescents to accumulate PA [11]. The current review focuses on outdoor POS, since outdoor spaces are more suitable for PA and a vast amount of adolescents' leisure time is performed outdoors [12,13]. In the last decade, the number of people residing in urban areas has increased by nearly 50% worldwide with this number expecting to rise to 66% by 2050 [14]. This will result in the expansion and densification of urban areas and will lead to a decrease in private green spaces (i.e. less people will have access to a private garden), which will increase the need for POS in urban areas [15].

Compared to primary school aged children, adolescents (aged 12 to 16 years old) have greater independent mobility (i.e. ability to roam in the neighbourhood without adult supervision) [16,17]. However, due to the restriction to obtain a drivers' license, they are still rather limited in their ability to visit places located at greater distances from their residence. Therefore, it is most likely that 12- to 16-year-old adolescents use POS differently compared to younger children or older adolescents. POS near adolescents' residences can be an important setting for PA. Moreover, previous research has shown that most adolescents use active transport (e.g., walk or cycle) to travel to parks or POS [17,18]. Therefore, increasing POS visitation (even when adolescents engage in sedentary activities after arriving at the POS) may lead to increased levels of PA due to active transportation.

An increasing number of studies have focussed on the association between various aspects of POS and PA. An extensive review of literature on general neighbourhood characteristics and PA among youth reported that access to parks and recreation facilities had inconsistent relationships with PA among youth [19]. Two other reviews have reported no association between access to POS and adolescent PA levels [20,21], whereas two systematic literature reviews (one on youth and one on all age groups) showed access to POS to be associated with higher levels of PA [22,23]. Furthermore, it appears from a previous research that POS are infrequently used by adolescents (aged 11-16 years old) [24-27]. In addition to these inconsistencies in findings on access to POS and PA and low usage of POS, there is very limited evidence on which POS characteristics are important to encourage adolescents to visit POS or to be active in POS. It is important to better understand what characteristics of POS can

encourage POS visitation and PA in POS among adolescents in order to design POS that encourage POS visitation and PA among this age group. Only one review by McCormack and colleagues previously investigated which specific POS characteristics are associated with park use and PA [28]. This review reported park attributes related to safety, aesthetics, amenities, maintenance and proximity to be important for encouraging park use and PA in parks. However, this review only included qualitative studies and solely included attributes of parks, whilst other types of POS could also be important locations for adolescents to be active. Furthermore, this systematic literature review included 21 studies, of which only five focused on adolescents and four of these five studies had very small samples ($n<20$). To the best of our knowledge, a systematic literature review including qualitative and quantitative evidence on specific POS characteristics associated with POS visitation or PA among adolescents is currently unavailable.

Therefore, the purpose of this systematic literature review was to gain deeper insights into which, how and why specific physical characteristics of outdoor POS may be related to adolescent POS visitation and PA by reviewing qualitative studies. Secondly, we reviewed quantitative studies to provide an overview of POS characteristics quantitatively associated with POS visitation and PA (performed in POS or general PA) among adolescents. Gaining insights into these POS characteristics of POS related to adolescents' PA is an important step to inform and guide the development of experimental studies exploring the causal association between POS characteristics and PA. Additionally, POS visitation and PA could be increased by knowing on which characteristics to focus. Information obtained from this review can also be used to inform urban planners in the development of PA-supportive POS.

METHODS

Before conducting the literature search, the review protocol was written and registered in the PROSPERO database [29] under the registration number: CRD42016045790. This systematic literature review adheres to the guidelines from the PRISMA statement (Preferred Reporting Items for Systematic reviews and Meta Analyses [30]) and a PRISMA-checklist is available in additional file 1.

SEARCH STRATEGY

Electronic searches were conducted in April 2017 in four electronic databases: Sportdiscus, MEDLINE (using the Pubmed interface), Web of Science and Leisure Tourism Abstracts. A comparable search strategy was used for each database and additional search filters were used where possible (e.g., to define the timespan or language). The search included search terms for 'adolescents' AND 'physical activity' OR 'public open space visitation' AND 'public open space'. The full search strategy can be found in additional file 2.

IN- AND EXCLUSION CRITERIA

The population of interest was healthy adolescents aged 12- to 16-years old (grades 1 to 4 of secondary school). Articles focussing on broader age groups were only included when the mean age of the participants was between 12 and 16 years or when results were reported for each age group separately. When the age range was broader than 12- to 16 years old and the mean age was not reported, the corresponding author was contacted. Subsequently, two articles were excluded, because the authors could not provide a mean age [31,32].

The search was limited to articles published in English between January 2000 (to report on recent literature) and April 2017. Only peer reviewed articles were included. No criteria were set concerning the research questions of the studies (e.g., research papers with the main aim to report on POS planning and design could be included when they also reported on characteristics of POS related to POS use and PA among adolescents as a sub-aim). Articles were excluded when they only reported general neighbourhood characteristics of POS (such as population density, general crime rates or access to parks) or social characteristics (such as other people being present at the POS).

Peer reviewed journal articles with both qualitative and quantitative research methods were included, however, studies with solely a methodological focus (e.g., to validate an audit tool) were excluded. A distinction between qualitative and quantitative research was made as suggested by a review article by Tuli et al. (2010) where qualitative methodology was characterized by having a flexible design and non-numerical analyses (e.g., focus group discussions), whereas quantitative methodology was characterized by a fixed design and statistical analyses (e.g., a study using questionnaires with closed-ended questions) [33].

Quantitative articles were required to have reported associations between specific physical characteristics of POS and POS visitation or PA among adolescents. Only articles examining associations with total PA, leisure time PA, PA in POS and active play were included. Subsequently, articles examining associations with school based PA, PA at home and transport related PA were excluded. PA levels could be measured by self-report (e.g., questionnaires) or objective measures (e.g., accelerometer). Qualitative articles were included when POS characteristics that were perceived positive or negative to visit or be physically active in POS were described using qualitative methods (e.g., interviews or focus group discussions) and they reported on (perceptions of) POS visitation, total PA, leisure time PA, PA in POS or active play (Table 1).

Table 1: In- and exclusion criteria

	In- and exclusion criteria
Population	– Mean age between twelve and sixteen years – Healthy adolescents (e.g., no patient groups) – General adolescent population (e.g., no elite athletes)
Setting	– POS accessible to all people (e.g., not school grounds during school hours) – Free access (e.g. no entrance fee)
Outcome	– Quantitative: Association between POS characteristic and POS use or PA (total PA, PA in POS, leisure time PA, active play) – Qualitative: Perceptions of POS characteristics and related to POS visitation or PA (total PA, PA in POS, leisure time PA, active play)
Publication Type	– Peer reviewed articles – Original research articles
Study design	– No methodological studies – No systematic literature reviews
Language	– Only articles written in English

ARTICLE SELECTION

All records retrieved from the search were imported into Endnote X7 (Thomas Reuters, New York) and duplicates were removed. Two researchers (LVH and AG) individually screened and selected all articles based on title (n=11,721), subsequently on abstract (n=1,907) and finally on full text (n=618) (Figure 1). Any disagreements were discussed with JVC, JV and BD until consensus was reached. Full texts were retrieved through the libraries of Ghent University and Vrije Universiteit Brussel and if needed through e-mail contact with the corresponding author of the article (n=1). Additionally, after the full-text review phase, a citation search was conducted for all included articles (forward tracking), reference lists of the included papers were screened to identify other eligible articles (backward tracking), and all authors searched their own databases for eligible articles. This additional search resulted in 62 records, which underwent the same systematic selection process as the articles initially identified (Figure 1). The total search resulted in 31 articles, of which 17 were qualitative and 14 quantitative.

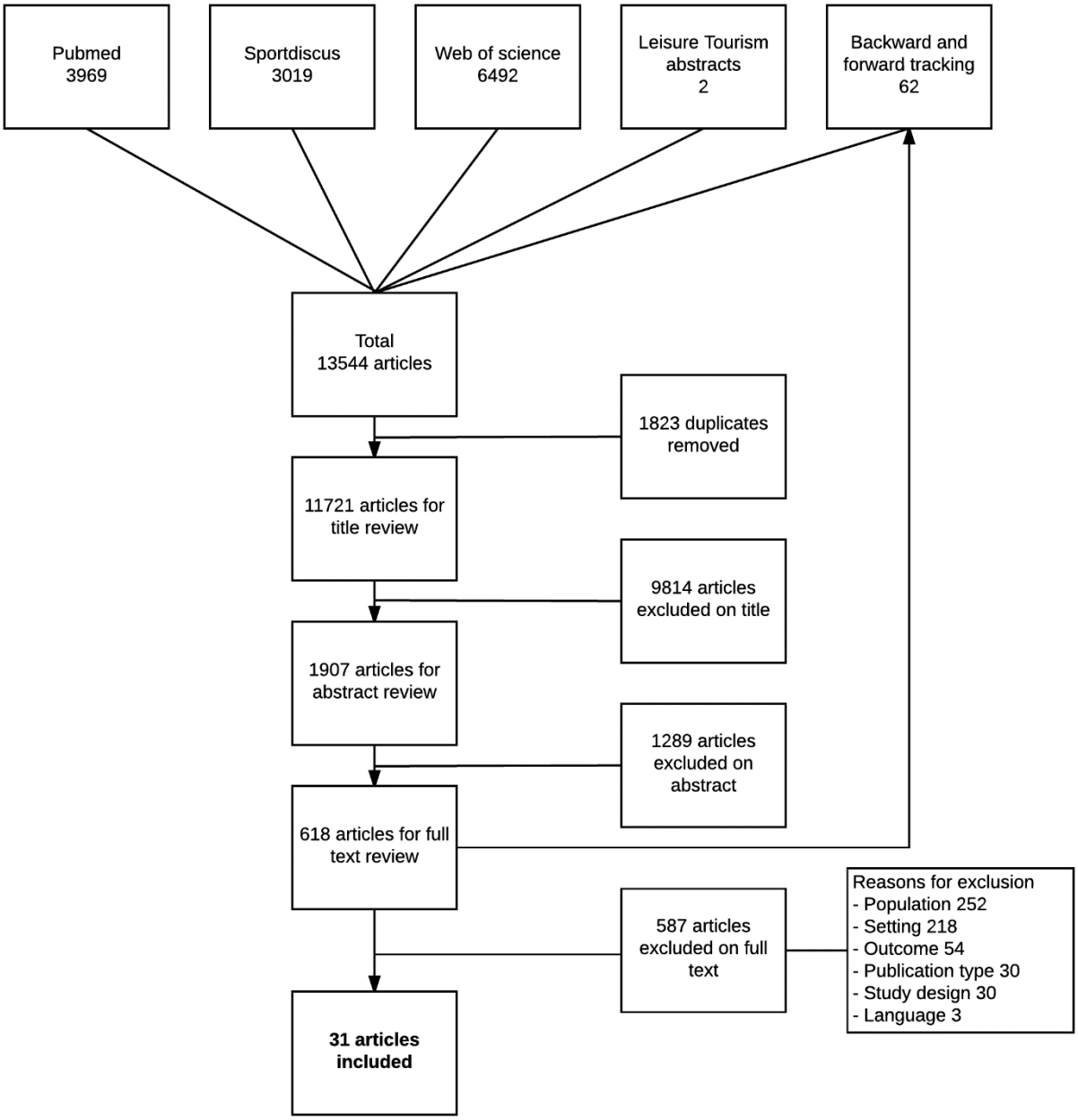

Figure 1: Flowchart of the conducted search strategy

DATA EXTRACTION

Data from the included articles were extracted by LVH and AG, entered in a standardized data extraction document and cross-checked to eliminate inaccuracies. General study information (e.g., study design, sampling method), study characteristics (e.g., place where study was conducted, data collection period), sample characteristics (e.g., ethnicity), measurement methods (for POS and outcome), specific POS characteristics, PA or POS visitation outcomes, and the associations between both were extracted. Only information available in the articles was entered in the data extraction file (i.e. no raw study data were requested from the authors). For all quantitative studies the characteristics that were significantly positively associated to POS visitation or PA were marked in the data extraction file with a “plus”, all significant negative associations were marked with a “minus”, and

non-significant associations were indicated with “zero”. Whilst for all qualitative studies, characteristics mentioned as being supportive for POS visitation or PA were marked in the data extraction file with a “plus” and all specific characteristics that were reported to inhibit POS visitation or PA were marked with a “minus”. A complete overview of the findings is available in additional file 3.

Classification of results

The relevant specific POS characteristics from the included articles were extracted and categorized according to pre-defined categories: features (facilities, amenities and general features of the POS), condition (maintenance, incivilities and upkeep), aesthetics (attractiveness and appeal), safety (personal security and fear) and policy (management, rules and restrictions). These categories were previously suggested for future research by Bedimo-Rung et al. [34] and used in a review by Mc Cormack et al. on characteristics of urban parks associated with park visitation and PA [28]. It is hypothesized that the features present in a POS will determine the type of usage of the POS [34]. Especially for PA, the absence or presence of features was hypothesized to be important. Furthermore, not only the presence of these features but also the condition and maintenance of the features and the POS in general can influence the attractiveness of a POS. More aesthetically pleasing POS are hypothesized to attract more (physically active) POS visitors as being in a pleasant environment can be motivating for POS visitation or PA [34]. In this systematic review, only characteristics directly related to fear or personal security were categorized under “safety”. It was hypothesized that feelings of unsafety could discourage POS visitation, as people generally try to avoid unsafe situations.

Quality assessment

The “standard quality assessment criteria for evaluating primary research papers from a variety of fields”-tool was used to score the included articles [35]. This tool contains two different checklists, (one for qualitative and one for quantitative studies) which contain ten and fourteen items, respectively. For the quantitative studies, items were scored depending on the degree to which the specific criteria were met (“yes” = 2, “partial” = 1, “no” = 0). Items not applicable to a particular study design were marked “n/a” and were excluded from the calculation of the summary score. A summary score was calculated for each paper by summing the total score obtained across relevant items and dividing by the highest possible total score (i.e.: 28 – (number of “n/a” x 2)). Scores for the qualitative studies were calculated in a similar way, based on the scoring of ten items; however, assigning “n/a” was not permitted for any of the items. The summary score for each paper was calculated by summing the total score obtained across the ten items and dividing by 20 (the highest possible total score).
The quality of all articles was scored by LVH and one of the co-authors (AG, JVC, BD, DVD, JV, PC) and disagreements were discussed until consensus was reached. The results of the quality assessment are reported in additional file 4 and the total score is included in Table 2. The quality score was not used to exclude low-quality studies from the review, but to inform the reader about the quality of included studies.

Data analyses

All POS characteristics that emerged from the qualitative and quantitative studies were summarized in Table 3 according to the five categories and all characteristics were described in detail in the text for each category. First al qualitative results were described, subsequently, it was then checked whether the explorative qualitative findings could be confirmed by the quantitative results.

In the results section, no distinction was made concerning POS visitation or PA for the qualitative results, since these were generally not addressed as separate concepts (i.e. during focus groups discussions or interviews, these were discussed interchangeably or in some studies the main aim was to discuss the use of POS; however, adolescents often talked about PA in POS as this was their main reason to visit a POS).

A complete overview of the results can be found in additional file 3. In this additional file, the quantitative results are presented separately for green spaces (land that is partly or completely covered with grass, trees, shrubs, or other vegetation e.g., parks, treed areas, meadows, fields [36]) and other POS (such as squares, streets or a combination of these with green spaces).

RESULTS

GENERAL CHARACTERISTICS OF INCLUDED STUDIES

All 31 studies (of which 17 had a qualitative and 14 had a quantitative design) included in this systematic literature review were cross-sectional studies and the number of participants ranged from 10 to 377 for the qualitative studies and from 92 to 42,563 for the quantitative studies. Except for one, all articles were published after 2007. Almost half of the studies originated from North America (USA: 12, Canada: 3, Brazil: 1), eight from Europe (Belgium: 2, Scotland: 2, UK: 2, Norway: 1, Spain: 1) and six from Oceania (Australia: 5, New Zealand: 1). Four articles were part of a larger study (two articles on the "Growing up Boulder" study, one article on the "Community Park Audit Tool" project and one article on the "Nuestra Voz-Our Voice" study) and about half of all studies collected data at schools (n=15). Almost all articles included perceptions, or measures of park or greenspace characteristics (n=25), sport fields and streets were studied in four articles and playgrounds and grass fields in three articles.

For the qualitative studies, the following methods were used most often: focus group discussions (n=10), use of photographs (n=6), drawing maps (n=5) and individual interviews (n=5). Fourteen of the qualitative studies reported perceptions of POS characteristics connected with POS visitation, three with PA in POS, four with general PA and two with active play in POS. Most commonly used methods to measure POS characteristics in the quantitative articles were audit tools (n=5), Geographical information systems (GIS) (n=3) and questionnaires (n=3), whilst the methods most commonly used to measure POS visitation or PA were questionnaires (n=5) and direct observations (n=5) (see Table 2). Eight of the quantitative studies reported POS visitation, six reported PA in POS and three reported leisure time PA. The quality of the articles ranged from 0.32 to 1.00 on a scale of 0-1. More than half of the studies scored more than 0.8 and only four scored less than 0.5

Table 2: Characteristics of included articles

QUANTITATIVE STUDIES								
	Study characteristics		Quality assessment	Population characteristics		Outcome (if applicable: broader outcome studied)		Measurement method of POS and outcome
Reference	Country	POS studied (if applicable: broader setting studied)	Range 0-1	Sample size	Age (Range or Mean years ± SD)	Gender (% girls)		
Aradi et al. (2016) [37]	Norway	Neighbourhood outdoor environment	**0.32**	149	14	n.r.	Neighbourhood outdoor environment use	POS + Outcome: Paper and digital maps + GIS
Baran et al. (2014)[38]	USA	Parks	0,95	1,301	13-18[a]	n.r.	Number of park users	POS variables: direct observation and GIS measures (O) Outcome: direct observation (O)
Edwards et al. (2015) [39]	Australia	Parks	0,95	1,304	12-15	51	Park use for PA	POS: aerial imagery, GIS, Auditing Tool (O) Outcome: Self-report questionnaire (S)
Esteban-Cornejo et al. (2016) [40]	USA	Neighbourhood parks	1,00	928	14.1 ± 1.4	50.4	PA in neighbourhood & PA in parks	POS: self-reported questionnaire NEWS-Y (S) Outcome: self-reported PA in Neighbourhood and PA in Park Scale (S)
Gallo et al. (2015) [41]	UK	Parks	0,77	1,210	11-20[a]	37.4	Park use and park based PA	POS: Observational Park Audit Tool Supplementary Assessments (O) Outcome: direct observation (O)
Janssen et al. (2015) [42]	Canada	Undeveloped green space in neighbourhood	1,00	5,138	13.1 ± 0.1	52.4	PA in free-time outside of school	POS: ArcGIS, Google Earth, Google earth street view tool (O) Outcome: Self-report questionnaire (S)
Loukaitou-sideris et al. (2010) [43]	USA	Parks	0,86	446	12 ± 0.9	53.8	Number of park users	POS: fieldwork, observation and archival information (O) Outcome: direct observation (O)
Reed et al. (2012) [44]	USA	Parks	0,72	604	13-20[a]	35.9	Number of park users	POS: SOPARC audit (O) Outcome: direct observation (O)
Reis et al. (2009) [45]	Brazil	Parks	0,86	42,563	14-18	59.6	Engagement in PA practice in parks	POS: questionnaire (S) Outcome: questionnaire (S)
Timperio et al. (2008) [46]	Australia	Closest public open space in neighbourhood	0,91	897	B: 14.6 ± 0.6, G: 14.4 ± 0.6	56.3	MVPA after school and MVPA in the weekend	POS: Short audit tool (O) Outcome: Accelerometer (O)
Thornton et al. (2017) [47]	USA	School playground	1,00	889	14.1 ± 1.4	50.3	MVPA after school (O) & PA at playground (S)	POS: Questionnaire (S) Outcome: Accelerometer (O) & Questionnaire (S)
Van Hecke et al. (2017) [48]	Belgium	Parks	0,95	216	13-20[a]	35.2	Number of park users	POS: audit SOPARC (O) Outcome: direct observation EARPS (O)
Veitch et al. (2016) [49]	Australia	Parks	0,91	99	13.3 ± 0.9	52.6	Park visitation and park PA	POS: Computer application with photographs (O) Outcome: Rating of characteristics (S)
Veitch et al. (2017) [50]	Australia	Parks	0,95	92	14.7 ± 1.0	57.6	Park visitation	POS: Computer application with written description of park attributes (O) Outcome: Ranking of characteristics (S)

[a] No mean age could be provided because of the measurement methods used [b] Focus group discussions total sample, [c] interviews, [d] all participants were in grade 1 and 2 of secondary school, [d] focus groups, [e] Photography, [f] No mean age could be provided, however only 21 (of 72) participants were older than 16; * Median; POS = Public open space; SD = Standard deviation; n.r. = Not reported; GIS = Geographical Information System; O = Objectively measured; S = Self-reported; USA = United States of America; PA = Physical activity; NEWS-Y = neighbourhood Environment Walkability Scale - Youth; MVPA = Moderate-to vigorous-intensity physical activity; UK = United Kingdom;; B = Boys, G = Girls,; SOPARC = System for Observing Play and Recreation in Communities; SOPLAY = System for Observing Play and Leisure Activity in Youth.

Table 2 continued

QUALITATIVE STUDIES								
	Study characteristics		Quality assessment	Population characteristics			Behaviour studied (if applicable: broader behaviour studied)	Measurement method of POS and behaviour studied
Reference	Country	POS studied (if applicable: broader setting studied)	Range 0-1	Sample size	Age (Range or Mean years ± SD)	Gender (% girls)		
Day et al. (2010) [51]	Scotland	Parks, streets and other informal spaces (local places)	0,60	49[b] 21[c]	13-14	n.r.	POS visitation	POS + behaviour: Focus group discussions and individual interviews
Derr et al. (2016a) [52]	USA	Park and greenway along a creek	0,45	70	12-16	n.r.	POS visitation (adolescents' perspective on inclusive POS)	2012: POS + behaviour: Field Trips with photo voice, photo grid; 2014: POS + behaviour: Field trips, design scenario critique, model-making
Derr et al. (2016b) [53]	USA	Diverse ecological landscapes such as a lake, trail corridor, boulder valley ranch	0,45	60	14-17 (15)	n.r.	POS visitation (things they did and did not like in POS)	POS + behaviour: Six hour workshop (photo voice method, facilitated drawing)
Gallerani et al. (2017) [54]	USA	Parks	0,80	50	11-18 (13.4±1.5)	66	Park visitation (experience with audit tools)	POS + behaviour: Focus group discussions
Guitart et al. (2014) [55]	Spain	Re-urbanized spaces (Public space)	0,45	n.r.	14-15	n.r.	POS visitation	POS + behaviour: Individual interviews (semi-structured, walk-along), focus group discussions
Holt et al. (2009) [56]	Canada	Parks and playgrounds (Neighbourhood PA opportunities)	0,85	59	12.4	47.5	Play and PA in POS	POS: individual interviews, GIS Behaviour: Individual interviews
Kirby et al. (2013) [57] [c]	Scotland	Parks, green space and sport fields (Local environment)	0,55	131[d] 63[e]	11-13	49.2[d] 52.7[e]	General PA	POS + behaviour: Drawing maps, photography, computer blogs and focus group discussions
Lloyd et al. (2008) [58]	Australia	Local urban parks	0,75	11	14-18 (16.0 ± 1.7)	100	Local park visitation	POS + behaviour: Individual interviews (semi-structured)
Morrow et al. (2001) [59]	UK	Patches of communal grass, streets, pieces of greenery, public parks and open spaces (Local environments)	0,65	102	12-15 (13.5)	n.r.	POS visitation and play (Perspective on and use of local environment)	POS: photographs/drawing maps, group discussions Behaviour: group discussions
Rehrer et al. (2011) [60]	New Zealand	Parks, beach, city centre (Favourite places)	0,60	173	12-13	42.2	POS visitation (Use of favourite places)	POS + behaviour: Drawing maps
Ries et al. (2008) [61]	USA	Parks and environment (Environment)	0,70	377	14-18 (15.5)	n.r.	General PA	POS + behaviour: Focus group discussion, sorting task
Roult et al. (2016) [62]	Canada	Outdoor recreational venues: soccer field, lawn areas, outdoor ice ring, football pitch, volleyball field and baseball field	0,85	72	12-17[f]	52.8	POS visitation	POS + behaviour: Focus group discussions

Slater et al. (2013) [63]	USA	Local parks, park field houses, school playgrounds and fields after school hours, parking lot, vacant lot (Neighbourhood Physical Activity Environments)	0,85	33	12-14	57.6	POS visitation	POS + behaviour: Focus group discussions
Smith et al. (2015) [64]	USA	Playgrounds, parks, sport fields, streets, yard spaces, courts/cul-de-sacs (Neighbourhood environment)	0,90	33	12-14 (12.5 ± 0.6)	60.6	PA in neighbourhood and general PA	POS + behaviour: Focus group discussions
Topmiller et al. (2015) [65]	USA	Parks and streets (Neighbourhoods surrounding urban trail system)	0,70	15	11-17 (14*)	87.0	POS visitation	POS + behaviour: Audit (self-reported), photographs (made by participants), focus group discussions, drawing maps
Van Hecke et al. (2016) [66]	Belgium	Squares, skate parks, parks, sport fields/playgrounds (POS)	0,85	30	12-16 (13.3 ± 1.1)	36.7	POS visitation and PA in POS	POS + behaviour: Individual interviews (Walk-along)
Winter et al. (2016) [67]	USA	Vacant lot (neighbourhood)	0,70	10	12.8 ± 0.6	60	POS visitation and general PA (barriers and facilitators for active living)	POS + behaviour: Mobile application on tablet including: geo-coded photos, audio narratives and GPS tracked walking routes

[a] No mean age could be provided because of the measurement methods used [b] Focus group discussions total sample, [c] interviews, [d] all participants were in grade 1 and 2 of secondary school, [d] focus groups, [e] Photography, [f] No mean age could be provided, however only 21 (of 72) participants were older than 16; * Median; POS = Public open space; SD = Standard deviation; n.r. = Not reported; GIS = Geographical Information System; O = Objectively measured; S = Self-reported; USA = United States of America; PA = Physical activity; NEWS-Y = neighbourhood Environment Walkability Scale - Youth; MVPA = Moderate-to vigorous-intensity physical activity; UK = United Kingdom;; B = Boys, G = Girls,; SOPARC = System for Observing Play and Recreation in Communities; SOPLAY = System for Observing Play and Leisure Activity in Youth.

FEATURES (FACILITIES AND AMENITIES) - QUALITATIVE RESULTS

Adolescents often perceived that age appropriate facilities were lacking in POS which discouraged their visitation [51,53,58,59,63,65] and PA in POS [59,64]. Adolescents sometimes felt like they were too old for the playgrounds and play structures that are common in many POS [51,58,59,63-65].

> "Like in parks, there is nothing to do for young people of my age, it's all for children, the swings and the slides. They should put things for us, as well." (Girl, age 13 to 14 years, 50).

However, two studies (mean age of participants 13.4 and 13.3 years) reported that playgrounds were perceived as positive for POS visitation [54,66] and PA in POS [66]. Another study reported that adolescents did use the playgrounds occasionally because there was not much else to do [51]. Facilities for younger children (e.g., playgrounds, slides and swings) were generally perceived as negative features by adolescents for POS visitation and PA in POS, because such facilities were perceived to be boring or childish. However, it was mentioned that these facilities could be useful when adolescents were accompanied by younger siblings [66]. Furthermore, adolescents suggested that diverse facilities for all ages should be present so adolescents can visit POS with younger siblings, parents or grandparents [52,66].

Adolescents mentioned sport- and recreational facilities (e.g., basketball courts, football pitches, indoor public swimming pools, bike tracks, BMX jumps, paths and trails) and play facilities (such as tree houses) to be positive characteristics of POS for visitation [51,52,54,60,66] and PA in POS [60,64,66] and general PA [57,61,64].

> "I live right by my church…there's a lot of basketball hoops and stuff like that. Also, there's a big tree that you can climb in. So there's a lot of things that you can do." (Girl, age 12 years, [64]).

Additionally, it was mentioned that adolescents like to alternate between different activities, therefore POS that provided opportunities for different activities were preferred [57,60,66]. Moreover, sport facilities with sufficient lighting [61] were perceived positively for general PA by the adolescents and multifunctional, small sport facilities were perceived positively for POS visitation [62]. However, one study reported that adolescents mentioned lighting not to be important because parks were not visited after dark due to safety concerns related to the presence of gangs at that time [63]. Sufficient lighting was also mentioned in relation to safety and the condition of the POS. Furthermore, sport fields that required additional equipment (such as badminton racquets) were perceived as negative characteristics for POS visitation and PA in POS [66].

Apart from these man made features, natural features such as creeks with foliage [52], ponds [66], trees to climb [66], less constrained outdoor spaces [64], open spaces and fields [52,60,61,64,66], and opportunities to interact with nature such as boardwalks, trails and bridges over a creek [53], were perceived as positive characteristics for POS visitation and PA in POS.

> "What I like here are the trees and the grass to sit on, on a square you can't sit on the ground or do anything and here we can have a picnic and do lots of other stuff." (Girl, age 15 years, [66]).

Additionally, adolescents mentioned that the open spaces required flat surfaces and good drainage to be perceived as a positive characteristic to encourage POS visitation [60]. Flexible green spaces were mentioned as a positive characteristic by adolescents because these can be used for various activities such as soccer or summer movie nights [52].

Adolescents often travel to POS by bike [17,18], therefore bicycle racks were perceived positive for visitation [53,66] and PA in POS [66]. Additionally, public transport linking to trails and sufficient car parking were also mentioned to encourage POS visitation in a study concerning larger POS located at the city's outskirts [53]. Adolescents described fences as a positive characteristic because they provided opportunities for PA in POS (i.e. throwing or kicking a ball against it), they can serve as a boundary marker for games and can provide some privacy such that adolescents could play without being watched by others. However, sometimes a fence was perceived as a barrier for active play [64].

Amenities such as toilets, drinking fountains, benches, comfortable seating with heaters, sheds, shelters, tables and BBQ facilities were mentioned by the adolescents as positive characteristics because they encourage POS visitation for a longer period of time. Only one study reported affordable food options, including food trucks, picnic tables and covered seating to be positive features for visiting a POS. In this study, the participants mentioned they only had 30 minutes to have lunch and having affordable food options and seating at the POS would make it more attractive [52]. Additionally, flags and symbols at the POS or cultural quotes along paths, representing the cultures and nationalities of the city were suggested to be positive characteristics for adolescent POS visitation. This was mentioned when a POS was studied located in an area that was previously inhabited by Native Americans [52]. Other cultural features proposed to stimulate POS visitation were a chalkboard, a performing arts stage and a sculpture garden [52].

Features (facilities and amenities) - Quantitative results

The qualitative results highlighted that playgrounds are often designed for younger children and that diverse facilities for all ages were perceived positive in order to visit POS in the company of their siblings. The quantitative results partly confirmed the qualitative results for POS visitation. The presence of a playground was unrelated to objective POS visitation in one study [38], but positively associated with objective park visitation in two studies [44,48] and preference for park visitation in one other study [49]. Furthermore, Veitch and colleagues found that adventurous play facilities, such as giant slides, swings, climbing equipment and a flying fox (i.e. age appropriate facilities), were elements which adolescents reported to be appealing [49,50]. Nevertheless, the suitability of the facilities (i.e. age appropriateness) measured objectively was not related to park visitation nor with PA [41]. However, only one study found positive associations between the presence of playgrounds and PA in POS, Veitch and colleagues found that adventurous playgrounds with swings, slides and climbing elements were ranked to be most important for being active in the park [49]. Whereas, no associations between the presence of a playground and PA were found by Edwards et al. [39].

Sport facilities were mentioned in the qualitative studies as supportive for POS visitation, which was confirmed by the quantitative studies. Sport activity zones and recreational facilities (i.e. walking paths, sport courts, BMX trails) were frequently found to be positively associated with *green space visitation*. The presence of basketball courts was positively associated with objectively measured [38,44] and preference for park visitation [49,50]. Presence of volleyball, baseball and handball fields were also positively associated with observed number of park users [44]. The presence of trails or walking paths was positively associated with green space visitation in two studies [44,48], with preference of parks

in two studies [49,50] but no association was found in one study [38]. However, in one study no association was found between the presence of sport facilities and park visitation [41]. Associations with visitation of other (non-green) POS were only described in one study that found positive associations between the presence of a sport field and visitation of outdoor neighbourhood environments [37]. The evidence for associations between the presence of sport fields and PA in POS was less strong. Associations between *green space* features and PA were described in seven different studies [39-41,45,47-49]. Objectively-assessed presence of activity spaces such as sport fields (e.g. soccer, baseball, and hockey) was unrelated to PA in one study with self-reported PA [39]. In other studies, painted sport goals on walls [49], ground markings [49], basketball/netball hoops [49], walking paths [39,48] and skateboard/BMX areas [39,49] were found to be positively associated with self-reported PA [39], objectively measured PA [48] and preference for PA [49]. The presence of basketball/netball hoops was not associated with self-reported PA in another study [39]. Additionally, the presence of recreational facilities and walking and cycling paths were unrelated to PA [46].

Qualitative results revealed that adolescents prefer POS where they can alternate between different physical activities and therefore, POS with a large variety of features were perceived as more supportive for visitation and PA. However, the number of activity facilities was unrelated to park PA in three quantitative studies [39,41,47] and the number of recreational facilities and playgrounds was unrelated to objectively measured PA in POS in one study [46]. Only one study found positive associations between the number of facilities and objectively measured park visitation [43] and another for self-reported PA in POS [47].

The participants in the qualitative studies indicated that supporting amenities such as shelters, benches and BBQ areas were supportive for POS visitation and PA. However, few quantitative studies examined these associations, therefore evidence to support these qualitative perceptions remains limited. The presence of a picnic area and a shelter were positively associated with objectively measured green space visitation [38]. Loukaitou-Sideris and colleagues found no association between overall park comfort (expressed as a sum score of presence of BBQ, restrooms, adequate seating, shade over more than 50% of the park, drinking fountains, vending machines, etc.) and overall park visitation. However, park comfort was positively associated with park visitation (number of adolescents) in the valley park studied and negatively associated with visitation in the inner city parks studied [43]. Only one study looked at associations between supporting amenities and PA in POS. The presence of BBQ areas, picnic tables and publicly accessible toilets was positively associated with PA whereas no associations were found in the same study for the presence of seating [39].

Natural features (such as trees, plants, water features) were indicated in some of the included qualitative articles as supporting for POS visitation and PA. In the quantitative studies, water features were positively associated with green space visitation in two studies [38,44]. Additionally, Aradi et al. found positive associations for objectively assessed presence of hilly terrains, varied terrains and grassy areas with visitation of outdoor neighbourhood environments [37]. However, one study found that the presence of water features and gardens [39] was not associated with PA at green spaces.

CONDITION (MAINTENANCE, INCIVILITIES AND UPKEEP) – QUALITATIVE RESULTS

Well-maintained and clean POS, and good and modern equipment were perceived positively by the adolescents for POS visitation [60] and general PA [64]. Consequently, a lack of cleanliness was often reported by adolescents as a negative characteristic for POS visitation [51,54,59,63,66,67], PA in POS

[56,59,64,66] and general PA [61,64,67]. Issues raised regarding cleanliness were: garbage, graffiti, dirt, dog mess, illegal dumping, broken glass, evidence of drug use (syringes) and bad smell.

Some adolescents stated that they did not have clean decent places to play [59]. Poor upkeep/maintenance of the sport fields/equipment (e.g., vandalized facilities, inoperable lights, poor rusted equipment, holes in fences) and poor upkeep/maintenance of the playing surface of sport fields (i.e. cracks in the courts, glass, uneven surface, poor ice quality in outdoor ice rinks, trash, leaves, rocks and syringes) were also described as negative characteristics for POS visitation [51,54,62,66], PA in POS [64,66] and general PA [61,64]. Cracks in the sidewalks were perceived as a negative characteristic for PA in general [61].

> Moderator – "Is there anything that makes a place somewhere you don't want to go?"
> "If it doesn't have, like, good equipment, like, some of the equipment's like rusted."
> (Boy, age 12 years, [60]).

The mechanisms through which the condition of a POS can affect POS use and PA may be via perceived feelings of safety, aesthetics or fear from being injured. For example, incivilities (such as graffiti, broken glass, evidence of drug use) may indicate the presence of undesirable users (see section about safety) which can affect perceived safety and the presence of badly maintained features could be perceived dangerous for injuries.

Condition (maintenance, incivilities and upkeep) – Quantitative results

The qualitative results emphasized that clean, well maintained POS and sport facilities with modern equipment encouraged POS visitation and PA. However, this was not confirmed by the few quantitative studies that examined these associations, additionally, only overall measures of maintenance were investigated. Two studies quantitatively examined associations between green space maintenance and green space visitation, of which one found a positive association [43] and one found no association [41]. Additionally, one study found no association between overall maintenance of the green space and objectively measured PA [41].

Aesthetics (attractiveness and appeal) – Qualitative results

Modern designs, new constructions as well as historical elements (such as a statue) attracted adolescents to POS (POS visitation and PA in POS) [52,55,66,67]. Beautiful sceneries with nature and greenery (i.e. lots of trees, river, attractive plants) and diverse habitat around trails encouraged POS visitation [52,53,60,66,67], PA in POS [66] and general PA [61,67] (mostly by girls).

> "I usually come here to jog, and when a place is green and open it motivates to be active. This is one of the reasons why I come to this park". (Girl, age 15 years, [66]).

Water features (such as ponds, fountains or rivers) and opportunities to interact with water were also perceived positively by adolescents for POS visitation [52] and general PA levels [57], however, adolescents sometimes considered water areas as unsafe (see safety section). It was also mentioned by the adolescents that a POS with lots of colours and graffiti at designated places (e.g. graffiti wall) were more attractive for visitation [51,52,66], PA in POS [66] and general PA [64]. In contrary, graffiti tags at non designated places, discouraged POS visitation and PA in POS [66].

> I think the graffiti is bad because it doesn't help the community at all…a lot of workers that do cement have to fix it…and it doesn't make the neighbourhood look any better.'' (Girl, [67])

AESTHETICS (ATTRACTIVENESS AND APPEAL) – QUANTITATIVE RESULTS

Qualitative results revealed that adolescents prefer POS with modern design, historical elements, colour, nature and green, water areas but without graffiti. However, only the presence of nature and green, water features and aesthetic value were examined in the quantitative studies.

Presence of greenness and landscapes were positively associated with objectively measured park visitation in one study [43], while environmental diversity and aesthetic value were unrelated to objectively measured green space visitation in another study [41]. Veitch et al. did find a positive association for the aesthetic value and landscape and greenness with preference for park visitation [49,50]. A positive association for self-reported PA with the presence of more than 25 trees [39] and with the percentage tree area over total land area [42] was found. No association was found between Normalized Difference Vegetation Index (NDVI) [39], tree canopy area [39] or percentage of meadows over total land area [42] and self-reported PA. Overall aesthetic value [41], environmental diversity [41] and the presence of a water feature [46] were unrelated to objectively measured PA. Furthermore, in one study, findings regarding the association between the presence of trees and PA were mixed, presence of trees was unrelated to moderate-to-vigorous PA (MVPA) in the weekend, but positively associated with MVPA after school [46].

SAFETY (PERSONAL SECURITY AND FEAR) – QUALITATIVE RESULTS

Poor maintenance and condition of POS and facilities were often mentioned in relation to feelings of safety. For example, lack of, or inoperable lights [51,52,61,66], unsafe surfaces (i.e. uneven grass, holes, lopsided surface, grass on basketball field) [62,63] and poor cleanliness (i.e. glass, syringes, broken bottles) [63,66] were considered barriers for POS visitation, PA in POS and general PA because they increased the risk of injury. Adolescents mentioned that they often came to the POS with their younger siblings and, therefore, the presence of safe features for children was perceived as a positive characteristic for POS visitation and PA in POS [66]. High levels of motorized traffic in and around POS was described as a deterrent for POS visitation [66] and PA in POS [65,66] and general PA [64], whereas safe road crossings were perceived as encouraging for POS visitation [53].

Another characteristic of POS that made adolescents feel unsafe and thereby made the POS less attractive to visit and use for PA were secluded/isolated areas (i.e. paths through wooded areas) where adolescents feared assault [51,66].

> "I like it here because it is a large and open space and you can see everything that is going on. It is good if there are some trees but not too much otherwise it is too secluded." (Girl, age 13 years). Similarly, a 14-year-old girl stated: "[. . .] it is open here, if something would happen, there will always be someone who would see it and come and help." (Girl, age 14 years, [66]).

Adolescents considered the presence of graffiti and vandalism to be associated with dangerous people being present at the POS. This was mentioned to negatively influence POS visitation [51] and general PA [64]. Another characteristic that is strongly linked to policy, is the presence of unleashed dogs, which are perceived by the adolescents as potentially dangerous and could possibly have a bad impact

on nature and wildlife. Therefore, the presence of fenced, off-leash dog areas was perceived as a positive characteristic to encourage POS visitation [53,54] and general PA [64]. In one US study, it was suggested that an emergency station would be a positive characteristic to increase feelings of safety and could thereby increase POS visitation [54].

Safety (personal security and fear) – Quantitative results

Participants in the qualitative studies emphasized that feelings of safety could influence the attractiveness of a POS for POS visitation and PA. However, most of the characteristics that were mentioned in the qualitative studies (graffiti, unleashed dogs, secluded areas and poor maintenance of facilities) were not included in the quantitative studies.

One study [43] investigated the association between safety of parks and objectively measured park visitation and found a negative association with overall park safety (i.e. more safety related features: e.g., police substations, park staff, lighting, emergency phones, was associated with less park visitors). Additionally, POS safety including amount of traffic and lack of lighting were negatively associated with POS visitation (i.e. less traffic and more lighting were associated with higher levels of outdoor neighbourhood environment visitation) [37].

Five studies investigated associations between safety and PA in POS [39,40,42,45,46]. Presence of lighting was positively associated with self-reported PA in one study [39], while perceived poor lighting was negatively associated with poor engagement in self-reported park PA among girls, but not among boys [45] and the presence of lights near streets was not related to objectively measured PA [46]. Inconsistent findings were observed regarding traffic safety. Presence of minor roads around parks [39] and the presence of low traffic speed roads were unrelated to self-reported PA [42]. Perceived dangerous traffic was negatively associated with low park PA among boys, but not among girls in one study [45], while a positive association between perceived overall traffic safety and self-reported PA was found in another study [40].

Policy (management, rules and restrictions) – Qualitative results

Rules and restrictions regarding ball games or any rules or restrictions in POS were mentioned as making POS less attractive to visit and to be active (in POS and in general). Signs that forbid ball games were regularly found at communal grassy areas located close to houses. Adolescents often felt like they had nowhere to go and play, make noise or play ball games and felt excluded because of signs that forbid ball games [59,61].

> “There is a sign with “No Ball Games” on a piece of greenery on my road. It stops children from playing typical games, but children need somewhere to play. […] They’ve got “No Ball Games” signs all over our streets and there are loads of little pieces of grass where kids could just play, and be like fairly happy and fairly safe, but they put up “No Ball Games” signs and that they can’t play there, and it’s like stopping from enjoying themselves.” (Girl, [59]).

Lack of information regarding the POS (e.g. information on the trails, natural history and safety awareness), lack of signage in and around the POS and absence of a map of the POS were perceived as negative characteristics for POS visitation [52,53].

POLICY (MANAGEMENT, RULES AND RESTRICTIONS) – QUANTITATIVE RESULTS

Two quantitative studies examined policy related associations. The allowance of dogs in the parks was not associated with self-reported PA in one study [39]. In another study, signage for dogs was positively associated with MVPA after school, but not associated with MVPA on the weekend [46]. Finally, the presence of signage restricting activities at POS was unrelated to MVPA after school and on weekends [46].

Table 3: Overview of qualitative and quantitative findings

	Qualitative[a]			Quantitative					
	POS use and POS PA			POS use			POS PA[b]		
POS characteristics	**-**	**0**	**+**	**-**	**0**	**+**	**-**	**0**	**+**
Features									
Age appropriate facilities[1] / lack of age appropriate facilities[2]	[58,59,63,65][2]		[53,64][1]		[41][1]		[45]*[2]	[41][1] [39][2]	
Sport activity zones/ exercise facilities /possibilities for PA	[66]		[51,52,57,60-64,66]		[38,41]	[37,38,44,49,50]		[39,49]	[39,49]
Playground	[51]		[53,54,66]		[38]	[44,48-50]		[39]	[49]
Walking/ cycling paths and trails			[53,54,61]		[38]	[44,48-50]		[46]	[39,48]
Large variety of features (for all ages); number of exercise facilities[3] / lack of variety of features[4]	[57][4]		[52,60,66][3]			[37,43][3]		[39,41,46,47][3]	[47][3]
Supporting amenities	[64]	[63]	[51,52,60-62,64,66]			[38]		[39]	[39]
Natural features			[52,53,66]			[37,38,44]		[39]	
Transport related features			[53,66]						
Lots of space/large size, open space/fields[5] / lack of space[6]			[60,61,66][5]			[38,43][5]	[45]*[6]		[39][5]
Cultural features			[52]					[39]	
Condition									
Lack of cleanness	[51,56,59,61,63,64,66,67]								
Poor upkeep/maintenance of sport fields	[51,61,62,64,66]								
Poor upkeep/maintenance of surfaces	[61,62,66]								
Well maintained/clean POS			[54,60,64]		[41]	[43]		[41]	
Good and modern equipment			[54,60]						
Aesthetics									
Aesthetic value					[41]	[50]		[41]	
Diverse habitat/environmental diversity			[53]		[41]			[41]	
Historical elements			[52,66]						
Colour: Ground and wall paintings			[52,64,66]						
Nature and green			[52,57,60,61,66,67]			[43,49]		[39,42,46]	[39,42,46]
Graffiti	[54,66]		[51,52]						

Safety									
Poor maintenance of POS and facilities	[61-63,66]								
Overall safety	[43]							[45]*	
High levels of motorized traffic	[65,66]			[37]					
Overall traffic safety/low traffic/safe road crossings			[53,64]					[39,42,45]*	[40]
Secluded areas	[51,66]								
Graffiti	[51,64]								
Unleashed dogs[7] / Dog park[8]	[64][7]		[54][8]						
Insufficient lighting[9] / Sufficient lighting[10]	[51,52,61,66][9]			[37][9]				[45]*[9] [46][10]	[45]*[9] [39][10]
Policy									
Rules and restrictions forbidding ball games/PA	[59,61]							[46]	
(Unleashed) dogs allowed (lack of policies)[11] / signage regarding dogs, fenced area for dogs[12]	[53,64][11]		[66][12]					[39][11] [46][12]	[46][12]
Lack of information and signage[13] / information about the park[14]	[52][13]		[54][14]						

a) All POS characteristics were measured subjectively except Topmiller et al. (2015) [65] used an audit tool and Holt et al. (2015) [56] used GIS measures.

b) Outcome = PA in POS unless reported otherwise: Veitch et al. (2016) [49]: outcome = "makes me want to be active", a ranking exercise was performed and ten characteristics ranked highest were reported in the table; Timperio et al. (2008) [46]: outcome = MVPA in the weekend[1] and MVPA after school[2]; Janssen et al. (2015)[42]: outcome = PA in leisure time outside of school; Reis et al. (2009) [45] reported "No engagement in park PA", these results were transformed for clarity of the table and indicated with a (*); Thornton et al. (2017) [47]: outcome= self-reported MVPA after school and objectively measured overall MVPA;

Only POS characteristics that were included in more than one study were included in the table, Similar characteristics were reported under a more generic term (e.g., a basketball field and soccer field were reported under "sport activity zones"), PA = physical activity; POS = public open space

DISCUSSION

The current review is the first to provide a systematic overview of existing qualitative and quantitative knowledge regarding POS characteristics associated or potentially influencing POS visitation and PA among adolescents. Summarizing the existing knowledge regarding characteristics of PA-supportive POS is important to inform and assist urban planners when planning to (re)design POS. Especially insights into POS characteristics associated with visitation and PA for adolescents is important, given that decreases in PA levels are strongest during adolescence [68].

Fourteen quantitative and seventeen qualitative studies were included in this review, all except one were published during the last decade. This indicates that interest in this topic is growing, but given the relatively low number of studies, evidence is currently limited. The number of quantitative studies examining similar POS characteristics was small (maximum 5 studies studied similar POS characteristics, 70% of the POS characteristics were examined in only one study), whereas many similar POS characteristics emerged from the qualitative studies. Additionally, many different measurement methods were used across the quantitative studies, with more studies using objective measurement methods (n=6), or a combination of objective and self-reported measures (n=5), compared to self-reported data (n=2). This variety in methods and design makes it difficult to formulate statements regarding the evidence of associations; however, some general preliminary observations can be formulated

It emerged from the qualitative results that adolescents perceive a lack of age appropriate features (e.g., sport fields and adventurous playgrounds) in POS and consider the features that are common in many POS (playgrounds with small swings and slides) to be designed for younger children [51,53,58,59,63-65]. Surprisingly, this has also been reported in previous research among children younger than 12 years old [28,69,70]. This suggests that extra effort is needed to ensure age appropriate and challenging features are provided in POS for both adolescents and children. Adolescents indicated that sport- and adventurous playgrounds would encourage POS visitation and PA. The quantitative evidence for this association is stronger for POS visitation than for PA. Regarding POS visitation, evidence suggests that presence of specific sport fields and adventurous playgrounds is positively associated with visitation [43,44,48-50]. Regarding PA, two studies found a positive association for the presence of sport fields with self-reported MVPA after school [47] and preference for PA [49]. However, no associations for the presence of sport fields with objectively measured PA [41,47] nor with self-reported PA [39] were found in three other studies. Additionally, an adventurous playground was associated with preference for PA in one study [49]. These results are supported by previous research reporting on a natural experiment, where it was shown that the instalment of playgrounds was associated with an increased number of people (of all ages) and with more people walking and being vigorously active [71]. Observational studies have reported that sport fields in parks have the highest number of park users and are used at highest energy expenditure among all age groups [72,73]. The few associations found for the presence of sport fields and adventurous playgrounds with PA could possibly be explained by the fact that other conditions should be fulfilled in order to stimulate PA (such as other adolescents to play soccer with, or good maintenance of the sport field [66]). However, sport fields and adventurous playgrounds can be considered attributes that may encourage POS visitation and PA across several age groups.

The presence of trails or walking paths was positively associated with POS visitation [43,44,48-50,74] and PA [39,48] in the quantitative studies and was also mentioned in the qualitative studies as an encouraging characteristic. Therefore, installing trails or walking paths could be a rather low cost adjustment to existing POS in order to encourage PA or POS visitation. Furthermore, the presence of walking paths and trails in parks was previously shown to be the park facility with the strongest relationship with park use for physical activity among adults [75].

The qualitative results indicated that POS had to be well maintained and aesthetically pleasing in order to be attractive for adolescents' POS visitation and PA. However, the concepts "maintenance" and "aesthetics" are very difficult to measure quantitatively as they are temporal concepts and are dependent on personal preferences (aesthetics) and recall bias when measured subjectively. This could explain the mixed results regarding associations for maintenance and aesthetics with POS visitation and PA in the quantitative studies. However, our results indicate that greenness, beautiful landscape and good maintenance could increase the attractiveness of a POS for visitation and PA, although evidence remains limited. Nevertheless, it has been shown that an aesthetically pleasing environment is associated with PA among adults [76,77]. Additionally, quasi-experiment in the US has shown that greening of vacant urban land (planting trees and grass), removing trash and regular maintenance activities was associated with residents reporting less stress and more exercise [78]. Therefore, ensuring good maintenance and creating aesthetically pleasing POS could be a valuable strategy to increase overall attractiveness of POS for visitation and PA.

For POS visitation, safety was only examined in two quantitative studies, of which one found an association in the unexpected direction [43]. Regarding PA, some quantitative evidence was found for the importance of lighting and low speed roads, which is consistent with the qualitative results [39,42]. However, other findings showed no associations between safety-related characteristics of POS and PA [39,45]. This is consistent with findings on associations between overall measures of neighbourhood safety and overall PA, for which (perceptions of) safety appear to be less important for adolescents than for children [79].

Based on our findings, it can be hypothesized that POS characteristics important for PA are similar as those important for POS visitation, i.e. presence of particular sport fields such as basketball fields, presence of walking paths or trails, and the presence of adventurous playgrounds. However, evidence is still very limited for several other features that may encourage POS use and PA, such as POS size, the number of features present, safety-related characteristics, maintenance-related characteristics and aesthetical features. Additionally, it is currently unclear what features may encourage PA when the main intention of the POS visit is not PA (e.g., how to induce PA when main aim was a picnic).

POS are places that are used by all age groups, therefore it is important to design POS to cater for users of POS across the lifespan and both males and females. However, it appeared that more male adults and children (aged 6-18) were present in park zones with a basketball court [38]. This indicates that attention should be paid to ensure facilities are attractive for males and females of all ages.

There were many methodological differences between the included quantitative studies. Most studies used combinations of objective measures of both the POS characteristics (via observations or GIS) and POS visitation. Two quantitative studies used a conjoint analysis and a ranking exercise to investigate preferences of POS characteristics for POS visitation [49,50] and POS PA [49] which does not make it possible to generate conclusions regarding actual POS visitation or PA within POS. Also comparing

these outcomes with other studies is somewhat difficult given the differences in outcome measures. Additionally, only two studies used accelerometers to objectively assess PA, expressed as overall MVPA [46,47]. The fact that the context of PA is not taken into account when using accelerometers may explain why these latter studies found few associations. It may be hypothesized that more associations would be identified if studies explored associations between POS characteristics and PA *in POS*, as it seems reasonable that POS attributes only affect POS PA, and not general PA. In the current study, seven studies investigated correlates of PA, of which two were on overall MVPA [42,46], while others explored to some extent the associations with PA within POS [39,40,45,47,49]. This may (partly) explain the high prevalence of null associations in the included studies.

It is advisable for future research to use objective outcome measures to assess PA in POS via observations or the combined use of GPS and accelerometer to indicate which locations are most often used by adolescents, and where adolescents spend their time when being physically active. In this review, none of the studies used a combination of GPS and accelerometers, suggesting that more research using these measurement methods is warranted. Additionally, the use of mixed methods could clarify quantitative results by using qualitative methods.

The included qualitative data revealed that girls prefer activities such as dancing, walking and basketball, whereas boys preferred activities such as soccer and biking [57]. Subsequently, different sport- and recreational features in parks may be preferred by girls compared to boys. The quantitative evidence suggests that playgrounds are used equally by boys and girls aged 0 to 18 years old [38], but that swings were more often used by girls [43]. Safety was another important theme mentioned more frequently by girls in the qualitative articles. This included safety from injuries in poorly maintained POS [66] and safety from assault (by people and dogs) [55,58,59] and discouraged girls to visit a POS unaccompanied. Moreover, Timperio et al. 2008 found that the presence of signage regarding dogs in the POS closest to home was associated with higher levels of accelerometer measured MVPA after school during week days among girls but not boys [46].

RECOMMENDATIONS FOR FUTURE RESEARCH

- Future research should include objective PA data *in* POS (e.g., with GPS and accelerometers) combined with validated audits of POS characteristics and qualitative research to ensure a comprehensive analysis of the topic.
- Future research should focus on the supportive characteristics of POS other than parks, such as playgrounds or squares within the neighbourhood.
- Additionally, there is a need for longitudinal studies and natural experiments to investigate causal relationships between changes in POS and POS visitation and amount of PA or PA intensity.
- Extra attention should be paid to user groups that are currently underrepresented in POS such as girls, woman [80], adolescents and older adults [81,82].
- Moderating effects of socio-economic status and cultural background should be taken into account in future studies.
- Future studies should also try to include multiple age groups, as POS have to be suitable for users of all ages and different preferences can exist between user groups.
- More research outside the US is needed.
- Additionally, socio-cultural POS characteristics (such as the presence of undesirable users) should be included next to physical environmental characteristics as socio-ecological models

emphasize the importance of both the physical and social environment. Especially among adolescents, for whom behaviour of peers or presence of other POS users may be of particular importance [13,83,84].

- Policy makers often have limited budgets, therefore research investigating the most important characteristics of POS that encourage POS visitation and PA among all age groups, is needed in order to provide clear instructions for the (re-)development of POS.
- In real life situations, multiple POS characteristics will be present simultaneously. Future studies should therefore investigate which combinations of characteristics elicit POS visitation and PA (e.g. by studying interactions between POS characteristics).

PRACTICAL IMPLICATIONS

The results of this systematic literature review provide a starting point for policy makers and urban developers when designing new POS or for POS renewal and it is recommended that future POS designers consider the following aspects. The presence of sport fields in POS will most likely encourage adolescents to use a POS. The presence of playgrounds was shown to be associated with POS use and PA among adolescents; however, the qualitative evidence showed that playgrounds are only perceived as encouraging POS visitation and PA when they are challenging and adventurous. Evidence for the associations between maintenance, aesthetical and safety-related characteristics is limited; however, adolescents indicated in qualitative research that these aspects do contribute to the attractiveness of a POS for visitation and PA.

STRENGTHS AND LIMITATIONS

This literature review is one of the first reviews to include multiple types of POS and both qualitative and quantitative research, which provides multiple perspectives. Previous studies only included parks and thereby decreased the generalisability and the comprehensiveness of the results. However, very few of the included articles reported results on the specific characteristics of less conventional places (e.g., vacant lots) for adolescents to visit or use for PA. These unconventional spaces should receive more attention in future research as they have the potential to be better utilized. Another strength was that a thorough review protocol was written and registered in PROSPERO database. Two independent reviewers screened all articles, extracted the data and performed the quality assessment to reduce the possibility of errors in the article screening process. This led to increased certainty about the accuracy of the included articles and data. Further, the characteristics of POS that were included in this review were categorized according to previously used categories to increase the comparability of the results with previous research. POS have to be designed to cater for the needs of all ages, therefore the results of this systematic literature review needed to be comparable to results of studies and review articles across other demographic groups.

The search was, however, limited to English literature and only four databases were searched, although these databases were anticipated to best cover the topic area. The search was limited to peer reviewed articles, and grey literature may have provided additional insights. However, only including peer reviewed articles ensured a high quality of the included research. This review focused on physical POS attributes associated with POS visitation or PA. However, from a socio-ecological perspective, individual, socio-cultural, and social environmental characteristics are also likely to explain some variance in POS visitation or PA [85] and the presence of combinations of these characteristics may be necessary to influence POS visitation and PA.

CONCLUSION

To conclude, this was the first review to provide an overview of qualitative and quantitative studies exploring the association between POS characteristics and POS visitation and PA among adolescents. Findings of the current review suggest that the presence of trails and walking paths, adventurous playground and some specific types of sport fields could be positively associated with both POS visitation and PA among adolescents. Aesthetics and safety-related characteristics seem to be less important for POS visitation and PA. We call for more studies using high quality methodologies (i.e. GPS and accelerometer to measure PA in parks and on-site observations using valid tools to assess POS characteristics) and in other types of POS than parks (such as playgrounds and squares) in order to inform urban planners when aiming to (re)design PA-supportive POS. Additionally, insights into individual and social factors related to POS use or PA are needed to obtain a socio-ecological approach to explain POS use and PA.

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ADDITIONAL FILES

ADDITIONAL FILE 1: PRISMA CHECKLIST

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, orboth.	p 1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	p 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is alreadyknown.	p 3-4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design(PICOS).	p 4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	p 5
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., yearsconsidered, language, publication status) used as criteria for eligibility, giving rationale.	p 5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date lastsearched.	p 5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	additional file 2
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in themeta-analysis).	p 6 and table 1
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and anyprocesses for obtaining and confirming data from investigators.	p 7-8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptionsand simplifications made.	p 7-8
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	p 8
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	/
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2 for each meta-analysis.	p 8-9

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	p 8-9
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	/
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	p 7
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	additional file 4
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	p9-19 and table 3
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	/
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	p 8-9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	/
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	p 22-23
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	p 25-26
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	p 26
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	p 1

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

ADDITIONAL FILE 2: SEARCH STARTEGY

#1 ‘adolescent’ OR ‘youth’ OR ‘adolescent’ OR ‘teen’

AND

#2 ‘physical activity’ OR ‘physical activities’ OR ‘physically active’ OR ‘physical exercise’ OR ‘leisure activities’ OR play’ OR ‘park visitation’ OR ‘park use’ OR ‘sport’ OR ‘exercise’ OR ‘leisure’ OR ‘recreation’ OR ‘walking’ OR ‘cycling’ OR ‘active play’

AND

#3 ‘environment’ OR ‘built environment’ OR ‘public open space’ OR ‘public space’ OR ‘open space’ OR ‘park’ OR ‘neighborhood’ OR ‘neighbourhood’ OR ‘public place’ OR ‘recreational facility’ OR ‘playground’ OR ‘trail’ OR ‘square’ OR ‘greenway’ OR ‘greenspace’ OR ‘urban space’ OR ‘field’ OR ‘park features’

Publication date 2000-2016

ADDITIONAL FILE 3: OVERVIEW OF THE FINDINGS

Additional Table 1: Overview of the quantitative findings regarding POS visitation

Objectively measured POS characteristics associated with …	**Objectively measured**			**Self-reported**		
	POS visitation			**POS visitation**		
	-	0	+	-	0	+
1. Green space visitation						
Features						
Presence of exercise facilities		[41]				
Number of exercise facilities			[43]			
Exercise facility suitability		[41]				
Trail or walking path		[38]	[44,48]			[49,50]
BMX Track						[50]
Basketball court			[38,44]			[49,50]
Volleyball court			[44]			
Baseball court			[44]			
Handball or tennis court			[44]			
Table tennis tables		[38]				[49,50]
Adventure playground		[38]	[44,48]			[49]
Gigantic/big slide						[49,50]
Climbing equipment						[49,50]
Swing						[49,50]
Flying fox						[49,50]
Pool or water feature			[38,44]			
Shelter			[38]			
Picnic area			[38]			
Park size			[38,43]			
Park comfort		[43]				
Condition						
Overall maintenance		[41]	[43]			
Aesthetics						
Aesthetic value		[20]				[50]
Environmental diversity		[20]				
Landscape & greenness			[43]			[49]
Safety						
Overall park safety	[43]					
2. Other POS visitation						
Features						
Hilly terrain						[37]
Varied terrains						[37]
Open cultivated area (grassy area)						[37]
Open cultivated area (sport field)						[37]
Safety						
Traffic				[37]		
Lack of lighting				[37]		

Additional Table 2: Overview of the qualitative findings regarding PA

	Objectively measured PA						Self-reported PA					
	Objective POS characteristics			Self-reported POS characteristics			Objective POS characteristics			Self-reported POS characteristics		
1. Characteristics of green spaces	**-**	**0**	**+**	**-**	**0**	**+**	**-**	**0**	**+**	**-**	**0**	**+**
Features												
Number of activity spaces		[41]			[47]			[39]				[47]
Sport fields (soccer, football, cricket, baseball, hockey, rugby, athletics)								[39]				
Exercise facility suitability		[41]										
Fitness Circuit								[39]				
Basketball/netball hoops								[39]	[49]			
Skateboarding/BMX									[39,49]			
Brightly painted sports goals on brick wall and ground markings									[49]			
Table tennis table								[49]				
Walking paths/trails			[48]						[39]			
Children's playground								[39]				
Playground (shaded)								[39]	[49]			
Playground features (Gigantic slide, swing, flying fox, wooden ship with rock climbing wall)									[49]			
Fountain or other water feature								[39]				
Gardens								[39]				
No features/Lack of equipment								[39]		[45]#		
BBQ									[39]			
Seating								[39]				
Picnic Tables									[39]			
Public access toilets									[39]			
Park size									[39]			
Lack of space										[45]#		
Condition												
Overall maintenance		[41]										
Aesthetics												
Aesthetic Value		[41]										
Environmental diversity		[41]										
Meadows (% land area)								[42]				

Treed areas (% land area)									[42]			
Number of trees >25									[39]			
High NDVI								[39]				
Tree canopy area								[39]				
Public art represent								[39]				
Safety												
Poor lighting											[45]#	
Lighting around courts, buildings, equipment									[39]			
Overall safety											[45]#	
Park surrounded by minor roads only								[39]				
Low speed roads (% road distance <50km/h)								[42]				
Overall traffic safety											[45]#*	[40]
Policy												
Dogs allowed								[39]				
2. Characteristics of other POS												
Features												
Number of recreational facilities		[46]										
Number of playgrounds		[46]										
Presence of cycling paths		[46]										
Aesthetics												
Trees and overhead coverage		[46][1]	[46][2]									
Water feature		[46]										
Safety												
Lights near streets/path		[46]										
Policy												
Signage regarding dogs		[46] [1]	[46] [2]									
Signage restricting other activities		[46]										

Outcome = PA in POS unless reported otherwise: Veitch et al. (2016) [49]: outcome = "makes me want to be active", a ranking exercise was performed and ten characteristics ranked highest were reported in the table; Timperio et al. (2008) [46]: outcome = MVPA in the weekend[1] and MVPA after school[2]; Janssen et al. (2015) [42]: outcome = PA in leisure time outside of school; Reis et al. (2009) [45] reported "No engagement in park PA", these results were transformed for clarity of the table and indicated with a (#); Thornton et al. (2017) [47]: outcome= self-reported MVPA after school and objectively measured overall MVPA; *= mixed results; PA = physical activity; POS = public open space; NDVI: Normalized Difference Vegetation Index (NDVI) = the number and size of tree canopies within or around the park (ranges between -1 and 1).

Additional Table 3: Overview of POS characteristics associated with visitation according to qualitative studies

Reference	Features	Condition	Aesthetics	Safety	Policy
Day et al. (2010) [51]	Sport facilities (football pitches) (+) Facilities for younger children (playground, swings and slides) (-) Shelter (+)	Poor maintenance and lack of cleanliness (litter, broken glass and syringes, dog foulness, dumping) (-) Vandalized facilities (-)	Graffiti at specific designated places (+)	Overgrown dark places (-) Poor street lights (-) Vandalism litter and graffiti (-)	
Derr et al. (2016a) [52]	Sport fields (athletic facilities, soccer field, basketball court and football pitch) (+) Play spaces for all ages (+) Tree houses (+) Creek access (+) Foliage by creek (+) Comfortable seating with bean bags and heaters (+) Food options (food stands, food trucks, picnic tables, covered seating) (+) Cultural features: Quotes along the paths, flags representing nationalities and cultures of Boulder, chalkboard, performing arts stage, sculpture garden (+)		Opportunities for interactions with water (+) Colour (+) Light art (+) Graffiti wall (+) Water fountains and interactive water play (+) Historical features (+)	Lack of lighting (underpasses along creek path are dark, unsafe and unwelcoming) (-)	Lack of good signage around the creek (-)
Derr et al. (2016b) [53]	Age appropriate playgrounds (+) Opportunities to interact with nature (boardwalks, trails and brigdges over a creek) (+) Paths (+) Public transportation to trail heads (+) Sufficient car and bike parking (+)		Diverse habitat on trails (+)	Safe road crossings (+)	Lack of off leash dog policies (-) Map of area (paper or digital) (+)
Gallerani et al. (2017) [54]	Trails (+) Playground (+)	General repairs of equipment (+) Cleaning of facilities (+) Graffiti (-)		Emergency station (+) Dog park (+)	Signage information on the elements present in the park e.g. map with features and amenities available in the park and for which age group the park is most appropriate (+)
Guitart et al. (2014) [55]			New construction (+) Modern design (+)		

Lloyd et al. (2008) [58]	Lack of age-appropriate facilities (-)				
Morrow et al. (2001) [59]	Lack of age-appropriate facilities (-)	Trampy (i.e. not very nice, dirty) (-) Dogs mess (-)			"No ball games"-signs (-)
Rehrer et al. (2011) [60]	Possibilities for PA (i.e. challenging, big variety) (+) Lots of space (+) Flat (+) Open space (+) Good drainage (+) Shelter (+) Modern equipment (+) Variety of things to do/facilities (+) Mountain bike tracks (+) BMX jumps (+) Good ground (+)	Clean (+) Good equipment (+)	Lots of trees (+)		
Roult et al. (2016) [62]	Multifunctional and smaller soccer, baseball and volleyball fields and football pitches (+) Outdoor recreational venues for multiple activities (+) Benches (+) Drinking fountains (+)	Poor quality of outdoor soccer fields (-) Mediocre ice quality in outdoor rinks (-) Garbage containers (+)		Deteriorated state of lawn areas (-)	
Slater et al. (2013) [63]	Lack of sufficient sport and play equipment (sport fields, dirt bike track) (G & B) (-) Lighting (B) (0)	Poor condition of features (garbage and spray paint) (G) (-)		Unsafe fields (uneven grass, holes in the ground, glass on the courts) (B) (-) Unsafe basketball court (lopsided, grass)(-)	
Topmiller et al. (2015) [65]	Lack of age appropriate features (-)			Car traffic (-)	
Van Hecke et al. (2016) [66]	Natural features (ponds and water features, trees to climb, green space, slopes or paths) (+) Playgrounds and play equipment (Swings, slides, sandpits and wooden constructions) (+) Sport infrastructure (Football pitches, basketball rings (+), badminton fields and table-tennis tables (-)) Water fountains (+) Toilet, (+) Bicycle racks (+) Sheds (+)	Lack of cleanness (garbage lying around, broken glass and illegal dumping) (-) Poor upkeep of facilities and play surfaces (sand or concrete, dangerous objects lying around: (e.g., glass or stones) and uneven playing surfaces: e.g., cracks) (-)	Beautiful scenery (nature, green) (+) Colour (+) Graffiti (-) Historical elements (statues and old buildings) (+)	Insufficient lighting (-) Poor maintenance of facilities (easy to get hurt) (-) Lots of traffic (-) Secluded areas and paths (personal safety) (-) Safe features for young children (+) Poor upkeep of facilities and play surfaces (sand or concrete, dangerous objects lying around: (e.g., glass or	Secluded area for dogs (+)

	Tables (+) Benches (+) BBQ spots (+) Picnic shelters (+) Diverse facilities for all ages (+) Large size (+)			stones) and uneven playing surfaces: e.g., cracks) (-)	
Winter et al. (2016) [67]		Garbage (-) Graffiti (-)	Attractive plants (+) Well maintained houses (+)		

All POS characteristics were measured subjectively except Topmiller et al. (2015) [65] used an audit tool; G = Girls, B = Boys

Additional Table 4: Overview of POS characteristics associated with PA (in POS and general PA) according to qualitative studies

Reference	Features	Condition	Aesthetics	Safety	Policy
Holt et al. (2009) [56]		Evidence of drug use (i.e. syringes) (-)			
Kirby et al. (2013) [57]	Football pitches (+) Basketball net (+) Not enough variety (-)		River (+) Greenspace (+)		
Ries et al. (2008b) [61]	Fields (+) Free space/open lots (+) Lights on basketball courts (+) Usable water fountain (+) Trails (+)	Poorly maintained facilities (-) Trash/litter (-) Cracks in the sidewalk (-)	Fields in the neighbourhood (+) Green space (+)	Poor lighting in certain areas (basketball court) (-) Unsafe facilities for PA (-)	Rules and restrictions (at places for PA) (-) Neighbourhood rules (e.g., no ball playing) (-)
Smith et al. (2015) [64]	Availability of age appropriate equipment (basketball hoops, less constrained outdoor spaces) (+) Fences (opportunity for physical play, boundary marker for game, privacy (+), barrier for physical play (-))	Condition of equipment (good (+) <-> poor, rusted equipment holes in fences) (-) Cleanness (no garbage, no graffiti (+) <-> presence of garbage, presence of graffiti/vandalism, bad smell (-))	Colourful and inviting equipment or space (+)	Low traffic (+) Graffiti (presence of unsafe people) (-) Fences (safety, unleashed dogs) (+)	Loose animals (-)
Van Hecke et al. (2016) [66]	Natural features (ponds and water features, trees to climb, green space, slopes or paths) (+) Playgrounds and play equipment (Swings, slides, sandpits and wooden constructions) (+)	Lack of Cleanness (garbage lying around, broken glass and illegal dumping) (-) Poor upkeep of facilities and play surfaces (sand or concrete, dangerous objects lying around: (e.g., glass or stones) and uneven playing surfaces: e.g., cracks) (-)	Beautiful scenery (nature, green) (+) Colour (+) Graffiti (-) Historical elements (statues and old buildings) (+)	Insufficient lighting (-) Poor maintenance of facilities (easy to get hurt) (-) Lots of traffic (-) Secluded areas and paths (personal safety) (-)	Secluded area for dogs (+)

	Sport infrastructure (Football pitch, basketball rings (+), badminton fields and table-tennis tables (-)) Water fountains (+) Toilet, (+) Bicycle racks (+) Sheds (+) Tables (+) Benches (+) BBQ spots (+) Picnic shelters (+) Diverse facilities for all ages (+) Large size (+)			Safe features for young children (+)	
Winter et al. (2016) [67]		Garbage (-) Graffiti (-)	Attractive plants (+) Well maintained homes (+)		

All POS characteristics were measured subjectively except Holt et al. (2015) [56] used GIS measures

ADDITIONAL FILE 4: QUALITY ASSESSMENT

Additional Table 5: Quality assessment qualitative articles

	Criteria												
	1	2	3	4	5	6	7	8	9	10			
Reference	Question/ objective sufficiently described?	Study design evident and appropriate?	Context for the study clear?	Connection to a theoretical framework / wider body of knowledge?	Sampling strategy described, relevant and justified?	Data collection methods clearly described and systematic?	Data analysis clearly described and systematic?	Use of verification procedure(s) to establish credibility?	Conclusions supported by the results?	Reflexivity of the account	Total sum	Total possible sum	Final score
Day et al. (2010)	2	2	2	1	1	1	1	0	2	0	12	20	0,6
Derr et al. (2016a)	1	1	2	1	1	1	0	0	2	0	9	20	0,45
Derr et al. (2016b)	2	2	2	0	1	1	0	0	1	0	9	20	0,45
Gallerani et al. (2017)	2	2	2	2	1	1	2	2	1	1	16	20	0,8
Guitart et al. (2014)	1	2	2	2	1	0	0	0	1	0	9	20	0,45
Holt et al. (2009)	2	2	2	2	1	1	2	2	2	1	17	20	0,85
Kirby et al. (2013)	1	1	1	1	1	2	1	0	2	1	11	20	0,55
Lloyd et al. (2008)	2	2	2	2	1	2	1	0	2	1	15	20	0,75
Morrow et al. (2001)	2	2	2	2	0	1	0	2	2	0	13	20	0,65
Rehrer et al. (2011)	1	2	1	1	0	2	2	0	2	1	12	20	0,6
Ries et al. (2008)	2	2	1	2	1	2	1	0	2	1	14	20	0,7
Roult et al. (2016)	2	2	2	2	1	2	2	2	2	0	17	20	0,85
Slater et al. (2013)	2	2	2	2	1	2	2	2	2	0	17	20	0,85
Smith et al. (2015)	2	2	2	2	1	2	2	2	2	1	18	20	0,9
Topmiller et al. (2015)	2	2	2	2	1	2	0	0	2	1	14	20	0,7
Van Hecke et al. (2016)	2	2	2	1	1	2	2	2	2	1	17	20	0,85
Winter et al. (2016)	2	2	2	2	1	2	1	0	2	0	14	20	0,7

Additional Table 6: Quality assessment quantitative articles

	Criteria													
	1	2	3	4	8	9	10	11	12	13	14			
Reference	Question/ objective sufficiently described?	Study design evident and appropriate ?	Method of subject/comparison group selection or source of information/input variables described and appropriate?	Subject (and comparison group, if applicable) characteristics sufficiently described?	Outcome and (if applicable) exposure measure(s) well defined and robust to measurement/misclassification bias? Means of assessment reported?	Sample size appropriate?	Analytic methods describes/ justified and appropriate?	Some estimate of variance is reported for the main results?	Controlled for confounding?	Results reported in sufficient detail?	Conclusions supported by the results?	Total sum	Total possible sum	Final score
Aradi et al. (2016)	2	1	2	0	0	0	1	0	N/A	0	1	7	22	0,32
Baran et al. (2014)	2	2	2	2	2	1	2	2	2	2	2	21	22	0,95
Edwards et al. (2015)	2	2	2	2	1	2	2	2	N/A	2	2	19	20	0,95
Esteban-Cornejo et al. (2016)	2	2	2	2	2	2	2	2	2	2	2	22	22	1,00
Gallo et al. (2015)	2	2	1	2	2	1	1	2	0	2	2	17	22	0,77
Janssen et al. (2015)	2	2	2	2	2	2	2	2	2	2	2	22	22	1,00
Loukaitou-sideris et al. (2010)	2	2	2	2	2	1	2	1	1	2	2	19	22	0,86
Reed et al. (2012)	2	2	1	2	2	2	0	N/A	N/A	1	1	13	18	0,72
Reis et al. (2009)	1	2	1	2	1	2	2	2	2	2	2	19	22	0,86
Timperio et al. (2008)	2	2	2	1	2	2	1	2	2	2	2	20	22	0,91
Thornton et al. (2017)	2	2	2	2	2	2	2	2	2	2	2	22	22	1,00
Van Hecke et al. (2017)	2	2	2	2	2	1	2	2	N/A	2	2	19	20	0,95
Veitch et al. (2016)	2	2	2	2	2	1	2	2	1	2	2	20	22	0,91
Veitch et al. (2017)	2	2	2	2	2	1	2	2	N/A	2	2	19	20	0,95

CHAPTER 3.2.

SOCIAL AND PHYSICAL ENVIRONMENTAL FACTORS INFLUENCING ADOLESCENTS' PHYSICAL ACTIVITY IN URBAN PUBLIC OPEN SPACES: A QUALITATIVE STUDY USING WALK-ALONG INTERVIEWS

Linde Van Hecke, Benedicte Deforche, Delfien Van Dyck, Ilse De Bourdeaudhuij, Jenny Veitch, Jelle Van Cauwenberg

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RESEARCH ARTICLE

Social and Physical Environmental Factors Influencing Adolescents' Physical Activity in Urban Public Open Spaces: A Qualitative Study Using Walk-Along Interviews

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Abstract

Most previous studies examining physical activity in Public Open Spaces (POS) focused solely on the physical environment. However, according to socio-ecological models the social environment is important as well. The aim of this study was to determine which social and physical environmental factors affect adolescents' visitation and physical activity in POS in low-income neighbourhoods. Since current knowledge on this topic is limited, especially in Europe, qualitative walk-along interviews were used to obtain detailed and context-specific information. Participants (n = 30, aged 12–16 years, 64% boys) were recruited in POS in low-income neighbourhoods in Brussels, Ghent and Antwerp (Belgium). Participants were interviewed while walking in the POS with the interviewer. Using this method, the interviewer could observe and ask questions while the participant was actually experiencing the environment. All audio-recorded interviews were transcribed and analysed using Nvivo 10 software and thematic analysis was used to derive categories and subcategories using a grounded theory approach. The most important subcategories that were supportive of visiting POS and performing physical activity in POS were; accessibility by foot/bicycle/public transport, located close to home/school, presence of (active) friends and family, cleanliness of the POS and features, availability of sport and play facilities, large open spaces and beautiful sceneries. The most important subcategories that were unsupportive of visiting POS and physical activity in POS were; presence of undesirable users (drug users, gangs and homeless people), the behaviour of other users and the cleanliness of the POS and features. Social factors appeared often more influential than physical factors, however, it was the combination of social and physical factors that affected adolescents' behaviour in POS. Easily accessible POS with high quality features in the proximity of adolescents' home or school may stimulate physical activity, if adolescents also experience a safe and familiar social environment.

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Competing Interests: The authors have declared that no competing interests exist.

Introduction

Regular physical activity has well-documented physical, mental and social benefits on adolescent health [1, 2]. Despite these well-known benefits there has been a decline during the past decades in physical activity levels of adolescents (12–18 years) worldwide [3–5] and in Flanders (Belgium) [6, 7]. The low levels of physical activity reported in adolescents [3, 4] are even lower in adolescents with low socio-economic status (SES) [6–10]. Adolescents with low SES have reduced opportunities to be active with fewer recreational resources near home [11] and are less likely to be a member of a sports club [6, 9, 12]. Moreover, adolescents with low SES experience more barriers to be active such as; high cost of activities, high safety concerns, less parental support and more family responsibilities (e.g., looking after younger siblings) [13, 14].

According to ecological models of health behaviour, physical activity is influenced by individual, social and physical environmental characteristics [15]. The physical and social environment where adolescents are active differs from that of children and adults. Adolescents aged less than 16 years are often restricted to the nearby neighbourhood due to their limited independent mobility (restriction to visit a POS located far from home unaccompanied by an adult and in Belgium the minimum age for driving a motorbike is 16 years) [16, 17]. However, adolescents have more independence compared with younger children [16] and they tend to spend a lot of their time outdoors with friends and family [18]. Considering these specificities of adolescents, public open spaces (POS) may be a promising setting to promote adolescents' physical activity [19, 20].

A POS is a public space with open access, that is accessible to all people independent of age, ethnicity, physical limitations, or other characteristics [21–23]. Some POS are under public ownership and management whereas others are private property but freely accessible and, therefore, also defined as a POS [23, 24]. POS can have different appearances such as parks, playgrounds and squares, but also streets, vacant lots and parking lots. In previous years, research on the relationship between the physical environment and physical activity in adolescence has increased [25–28], with studies reporting contradictory results on the importance of the accessibility and availability of parks, recreational facilities, opportunities to exercise and physical activity facilities [25, 28–32]. Some found no association [25, 28, 32, 33], whereas others found a positive association between proximity to parks, availability of recreational facilities, opportunities to be active and physical activity among youth [29–31]. These inconsistent results may indicate that other POS characteristics such as specific physical features of POS (e.g., trees that provide shade), quality of features, and the social environment (e.g., use by friends) play an important role in determining whether or not adolescents visit and use a POS for physical activity.

Little is known about the specific characteristics of POS that influence physical activity in adolescents. A previous study showed positive associations for the presence of trees providing shade and presence of signs regarding dogs with adolescent girls' leisure-time physical activity in POS [20]. Most other research focused on one specific location such as parks or green space [34–36]. Furthermore, little is known about the social aspects of POS that are related to adolescents' physical activity. Some research has focused on the social aspects of parks; park use by friends was associated with park use among adolescents [35] and opportunities for social interactions made parks more attractive for adolescent girls [34].

Besides physical activity in POS, active transportation (walking and cycling) could also contribute to overall physical activity levels. Most adolescents' trips to parks are performed by foot or bike [17], and adolescents' active transportation is positively associated with daily physical activity [37]. Accordingly, POS that are attractive to visit may increase overall physical activity levels (physical activity in the POS and active transportation to the POS).

Some previous studies included both factors of the physical and social environment [18, 36, 38–40]. However, the interplay between the social and physical environment remains unclear

[18, 19, 35, 41, 42]. This may be due to the fact that these studies only included a few social environmental factors (e.g., crime or park use by friends) and these factors were not context-specific (i.e., they were not measured in the POS that were actually used). Limited research has studied social and physical environmental characteristics of POS simultaneously and this has not been studied yet in Europe. This indicates that there is need for more research on the physical and social characteristics of POS related to physical activity in adolescents.

Most research conducted in this area is quantitative survey research [20, 25, 27, 43]. However, the importance of physical aspects of POS are difficult to measure quantitatively because they are subject to various social factors and vice-versa. Qualitative research can provide more in-depth information and the opportunity to gain insight in to which characteristics of POS influence visitation, and how these characteristics may influence physical activity [15, 44]. Individual or focus group interviews are often used for qualitative research [38]. However, this method requires that the interviewee remembers all the impressions, experiences and events that happened in the POS while he/she is not present in the POS. Consequently, it is difficult to obtain in-depth information on the physical and social environmental context and information may be lost. Conducting interviews while walking within the POS (a walk-along interview), means that it is possible to study participants' interpretation of the POS while experiencing it and thus uses the advantages of both face-to-face interviews and observations [44]. This methodology was previously utilized in a younger age group (7-to-9-year-olds) by Loebach and colleagues, to capture children's use and perceptions of their neighbourhood [45]. This methodology creates an interplay between the environment (both social and physical), the researcher and the participant which can lead to in-depth information and new insights in the interplay between these environments.

This study used walk-along interviews in POS located in low SES neighbourhoods. The aim of this study was to identify the physical and social environmental factors influencing adolescents' visitation and physical activity in POS located in neighbourhoods with low SES.

Methods

Participants and setting

Adolescents aged 12 to 16 years were recruited by face-to-face contact in POS in low SES neighbourhoods through purposeful convenience sampling until saturation of information was reached (final sample size = 30). When the participants agreed to participate, the interview was immediately conducted at the POS where they were recruited. Participants were recruited from thirteen different POS (3 squares, 2 skate parks, 6 parks and 2 sport fields/playgrounds) in eight neighbourhoods. Streets, vacant lots and parking lots were also visited to recruit participants. However, at these POS no adolescents were found. The POS were selected based on the advice of a youth worker and were located in three different Flemish cities (Brussels, Antwerp and Ghent) which are located within a radius of 50 km from each other. The size of the POS ranged from 507m² (square) to 190,760m² (park) with a mean area of 42,347m². Data collection was performed during daytime, on weekdays after school and on weekend days from July to October 2014 in neutral to good (i.e., not raining) weather conditions.

Low SES neighbourhoods/communities were selected based on population density, unemployment rates, welfare index and per capita income [46]. Population density (ranging from 6,920 inh/km² to 26,193 inh/km²) and unemployment rates (11%-36%) of the selected neighbourhoods were higher than average city values. Per capita income (€10,767-€15,913) was lower than average city values. The welfare-index ranged from 62–103. This is an indication of the income of the neighbourhood/community compared to the mean income in Belgium, with 100 considered a good welfare. The percentage of people with a nationality other than Belgian residing in the neighbourhood ranged from 22% to 46% [47–50].

Because 12 to 16 year olds were interviewed on a non-sensitive topic, it was opted to obtain an active consent from the participants and a passive consent from the parents or guardians [51, 52]. Participants indicated their consent by signing an informed consent form after the informed consent was read to them (to make sure all participants fully understood the written consent), additionally verbal consent was also given and audiotaped. The parents or guardians were given the opportunity to refuse participation of their children through a letter that was given to the participants. Without refusal, consent was assumed. This consent procedure and the research protocol for minors were approved by the medical ethics committee of the University Hospital of the Vrije Universiteit Brussel (BUN 143201420501) and the medical ethics committee of the University Hospital of Ghent University (EC/068-2015/mf) referring to the privacy act of December 8th, 2012 on the protection of privacy in relation to the processing of personal data [53]. Informed consent was obtained from all participants and all participants gave permission to use their quotes in research publications.

Procedure and measurements

The interview consisted of three consecutive parts which were all audiotaped. The first component of the interview included questions that assessed demographics (age, sex, place of birth), frequency of visiting a POS (in a usual week), duration of a usual visit, activities in POS, satisfaction with number of POS in the neighbourhood, transport modes to POS, sport club membership and frequency of attending sport club and SES (parents' jobs [54]). Participants were defined as low SES when none of the parents performed a white collar job.

Second, questions assessing the social environment were asked. These open-ended questions are described in Table 1 and were used to prompt a conversation about the social environment and to gain more insight and in-depth information on social context, modelling, social networks and social trust and cohesion.

Third, a semi-structured walk-along interview was conducted in the POS where participants were recruited. The participant and researcher walked through the POS while conducting the walk-along interview. These walk-along interviews were conducted in Dutch and lasted 30–40 minutes.

Before starting the walk, the following instructions were read: "*We are now on place X. We would like to know more about the characteristics of this POS that encourage or discourage you to visit this POS and about the characteristics that encourage or discourage you to be active at this POS. First, you can tell us about the characteristics that are encouraging or discouraging to visit, and secondly you can tell us about characteristics that are encouraging or discouraging to be active. By physically active we mean all but sitting activities. This includes for example standing, playing games, doing sports, recreational activities or exercise. Think about the things that are more or less pleasant, interesting or attractive to visit or to be active on this space. What makes it fun to be here and to be active here? Also consider things that affect your feelings of*

Table 1. Questions used to assess the social context.

Topic	Questions
Social context	With whom do you come here?, Are there gangs hanging around?, Is there a lot of drug use?
Modelling [55, 56]	Are your friends and family active?, Do your friends often ask to hang out?, Are there lots of other people active here?
Social network [55, 57]	Do you know lots of people in the neighbourhood?, Are there lots of other adolescents to do things with?
Social trust and cohesion [56, 58]	Are people around here willing to help their neighbours?, Is it a close-knit neighbourhood?, Can people in this neighbourhood be trusted?, Do people in your neighbourhood generally get along well?

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safety. This can include safety from traffic and safety from crime, but also safety of being injured. Thus, think about all positive and negative things in this place that affect how you experience visiting and being active. You are the expert and it is the purpose that you tell us freely about your experiences, ideas and opinions, so that we can learn about the things in this POS that are encouraging or discouraging for you to visit or to be active here. Therefore, we may ask some additional questions to completely understand your experiences, ideas and opinions. All the information gathered will be strictly confidential and will only be used for our research. All things that you talk about, will be photographed. Is everything clear to you? As it is too difficult to write down the complete interview, it will be tape recorded. Do you agree with this?"

When participants did not have the tendency to share experiences and opinions spontaneously, the interviewer stopped at regular (and random) moments during the walk and asked the following questions: *Are there characteristics that are encouraging or discouraging to visit, or to be active? Think about the things that are more or less pleasant, interesting or attractive to visit or to be active in this space.*

Participants who completed the walk-along interview were also asked if they were willing to complete a second interview at a POS that they do not usually visit to capture reasons for not visiting that POS. This second POS was selected by the interviewer after consulting with the participant and this second interview was conducted directly after the first interview. Seven participants were willing to participate in this second walk-along interview.

Data analysis

Data from the first and second part of the interview were used to calculate descriptive statistics in SPSS version 22. Qualitative data from the audiotaped walk-along interviews and the social environmental questions were transcribed verbatim and analysed using Nvivo 10 software. Data analysis was guided by a grounded theory approach, which consists of systematic, yet flexible, guidelines for collecting and analysing qualitative data to construct theories from the data [59]. First, the walk-along interviews were read carefully, followed by inductive coding and assigning all mentioned physical and social environmental factors to subcategories. These subcategories were identified during the transcribing process based on frequently recurring themes. Finally, these subcategories were grouped into more general categories (Table 2). The assignment of the subcategories and grouping into categories was performed by two researchers (LVH and JVC) and disagreements were discussed until agreement was reached. For the physical environment, the categories were named consistent with previous literature on characteristics of parks associated with park use and physical activity [60, 61]. These categories include accessibility and location, features, aesthetics, upkeep, safety and policy.

Qualitative research can be supported by using quantitative counts of the number of times a certain topic was mentioned to indicate certain patterns or emphasize recurring themes. As recommended by Sandelowski (2001), the following classifications for cited topics were used: when a topic was mentioned by less than 25% of the participants it was referred to in the text as "a few", by 25%-50% it was referred to as "some", by 50%-75% it was referred to as "many" and by >75% it was referred to as "almost all" [62]. This approach has been used previously in research with similar methodologies by Van Cauwenberg et al. [63].

Results

Descriptives

Descriptive characteristics of the sample are presented in Table 3. The sample (n = 30), aged 13.3 ± 1.1 years, consisted of 63.3% boys and 86.7% of the participants were born in Belgium. All participants lived in an urban (>600inh./km²) or suburban (300-600inh./km²) [64] area

Table 2. Overview of the physical and social environmental factors affecting visitation and physical activity in POS.

PHYSICAL ENVIRONMENT		Mentioned by few/some/many/almost all participants			
Categories	**Subcategories**	**few**	**some**	**many**	**almost all**
Accessibility and location	Close to home			X	
	Close to other locations		X		
	Presence of pubs and restaurants[a]	X			
	Well-known location	X			
	Accessibility by foot, bike and public transport				X
Features	Natural features				X
	Man-made facilities				X
	Diverse facilities for all ages		X		
Aesthetics	Beautiful scenery (nature and green)			X	
	Colour and graffiti[a]	X			
	Historical Elements	X			
	Noise[a]/quietness	X			
Upkeep	Cleanliness			X	
	Upkeep of facilities and playing surfaces		X		
Physical aspects of safety	Lighting	X			
	Safety from being hurt (maintenance of facilities)		X		
	Safety from traffic		X		
	Secluded areas[a]	X			
	Safety of accommodation for young children	X			
Policy	Organized activities		X		
	Secluded area for dogs	X			
SOCIAL ENVIRONMENT					
Categories	Subcategories	few	some	many	almost all
Social network	Friends and family				X
	Nice atmosphere	X			
	Knowing lots of people in the neighbourhood				X
	Other adolescents to play with/Social contact				X
Other Users	Behaviour of other users[a]				X
	Ethnicity of other users	X			
	Number of other users		X		
Social aspects of safety	Undesirable users[a]				X
	Presence of other people	X			
	Safety at night		X		
Parents	Habit (taught by parents)	X			
	Rules from parents		X		
Privacy	Privacy		X		
Modelling	Active use by others			X	
	Family active	X			
	Friends active				X

A few = topic mentioned by < 25% of participants, Some = topic mentioned by 25%-50% of participants, Many = topic mentioned by 50%-75% of participants, Almost all = topic mentioned by >75% of participants.

All subcategories mentioned in the table were mentioned by the participants to encourage POS visitation and/or physical activity unless stated otherwise.

[a] Categories that were mostly mentioned to discourage POS visitation and/or physical activity.

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and 62.5% of participants had a low SES based on occupation of both parents. Almost all participants (86.7%) visited a POS at least once a week and stayed there almost 2.5 hours. The most reported activities in POS (boys and girls) were soccer and basketball. An overview of the activities that participants engaged in, is presented in Table 4. Many participants (66.7%) were satisfied with the number of POS in the neighbourhood. Transport modes used to travel to a POS were walking (82.8%), bike/skateboard/rollerblade (31.0%) or public transportation (24.1%). Only 10.3% of the participants indicated that they travelled to a POS by car. In this sample, 46.7% of the participants were members of a sport club and attended this club on average 3.6 times per week.

Part 1: Physical environment

Accessibility and location. Almost all participants mentioned at least one aspect of accessibility of the POS where they were interviewed. POS located close to their home were visited more often than POS located further away. Almost all participants indicated that good access by foot, bike and public transportation was important for visiting a POS. Some participants indicated that POS located close to other destinations such as schools, shops, the city centre or

Table 3. Descriptive statistics of the sample (n = 30).

Demographics	
Age (years) (M ± SD)	13.3 ± 1.1
Girls (%)	36.7
Born in Belgium (%)	86.7
Occupation Father (%)	
Blue collar worker	45.8
White collar worker	29.2
No Principal occupation	25.0
Occupation Mother (%)	
Blue collar worker	38.5
White collar worker	11.5
No Principal occupation	50.0
Physical activity and POS use	
POS visitation at least once a week (%)	86.7
Average duration of stay on a usual visit at the POS (M ± SD)	146.8 ± 90.2
Satisfied with the number of POS in neighbourhood (%)	66.7
Mode of transport to travel to a POS (%)	
Walking	82.8
Bike/skateboard/roller-skates	31.0
Public transport	24.1
Car	10.3
Active member of a sport club (%)	46.7
Frequency attending sports club (times/week) (M ± SD)	3.6 ± 3.2
Social context	
Accompaniment to POS (multiple answers possible) (%)	
Alone	14.3
Friends	71.4
Family	46.4
Organization	3.6
Participants indicating drug use in the POS (%)	63.3
Participants indicating gangs hanging around in POS (%)	60.0

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a friend's house were used more frequently because they like to combine multiple activities. Additionally, well-known centrally located POS were easier to meet up with other friends. For example, one 15-year-old girl said: *"This is the park closest to my home and a lot of my friends live nearby. This is the place where we meet up because it is close for everyone. . . . Sometimes we go to those shops over there or we take the bus from here."* (Girl 1, 15 years)

The presence of shops nearby a POS was mentioned by a few participants as important, as they would buy some food and drinks for a picnic at the POS. These shops were also important as they provided the opportunity to buy drinks after being active. POS should not be too close to a pub or bar because that would limit the possibilities to play, be active and make noise. *"I like it that there are many people here but I don't want to bother them, they are eating and drinking at the restaurants and pubs and I don't want to disturb them."* (Girl 5, 15 years).

Features. Several kinds of features of POS were mentioned by the participants to attract them to visit a POS and to encourage them to be active. These features were of natural origin (e.g., ponds and water features, trees to climb, green space, slopes or paths) or man-made (e.g., play equipment, basketball rings, benches, BBQ spots, picnic shelters or toilets). Some participants mentioned large open spaces with some trees and grass as being important (Fig 1). "*What I like here are the trees and the grass to sit on, on a square you can't sit on the ground or do anything and here we can have a picnic and do lots of other stuff."* (Girl 4, 15 years). The size of the POS was also important for adolescents who like to play sports, such as soccer or basketball. *"This is a large space, and in some parks there are too many trees and not much space to play. It is not really supportive when there is a tree in the middle of the soccer field."* (Boy 2, 12 years). For adolescents who like to jog or cycle in POS, paths with slopes were perceived as positive because they increase the training intensity (Fig 2).

Playgrounds and sport fields were considered attractive features for adolescents to visit and be active in POS (Figs 3 and 4). However, only the younger participants (12–13 years old) mentioned swings, slides, sandpits and wooden constructions as positive facilities where they can play hide and seek, tag or invent their own games. Many participants (mostly boys) mentioned sport fields and especially soccer fields as being important to encourage physical activity.

Table 4. Activities performed in POS by the participants.

Girls (n = 11)	%(n)	Boys (n = 19)	%(n)
Dancing	9.1 (1)	Baseball	5.3 (1)
Frisbee	9.1 (1)	Climbing trees	5.3 (1)
Playground	9.1 (1)	Fantasy games	5.3 (1)
Roller-skating	9.1 (1)	Tennis[a]	5.3 (1)
Sledging (winter)	9.1 (1)	Badminton	10.5 (2)
Sitting	9.1 (1)	Playground	10.5 (2)
Tag	9.1 (1)	Hide and seek	15.8 (3)
Talking with family	9.1 (1)	Skateboarding	15.8 (3)
Ball games	18.2 (2)	Tag	15.8 (3)
Basketball	18.2 (2)	Jogging	21.1 (4)
Fantasy games	18.2 (2)	Table tennis	21.1 (4)
Go for a walk	18.2 (2)	Basketball	31.6 (6)
Jogging	18.2 (2)	Soccer	78.9 (15)
Soccer	27.3 (3)		

Participants were asked what kind of activities they engaged in when they went to the POS where the interview took place. They could provide as many answers as they preferred.

[a] Tennis court was not available, therefore, they played tennis on the grass field.

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Fig 1. Large open spaces with grass and some trees encourage adolescents to be active. Park van Vorst, Brussels.

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However, sport facilities, such as badminton fields and table-tennis tables, were rarely used because participants did not have the necessary equipment to use the facilities. Other amenities such as water fountains, toilets, bicycle racks, sheds and tables encouraged adolescents to visit a POS.

Above all, the diversity of the features and thereby the possibility to engage in many different active and sedentary activities was important. Some participants also mentioned that they liked facilities that were appropriate for multiple age groups, so that adolescents who have to babysit their younger siblings can bring them to the POS.

Fig 2. Paths with slopes are encouraging to be active for joggers and cyclists. This was mentioned by the participants because it increases the training intensity. Park van Vorst, Brussels.

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Fig 3. Playgrounds are important for younger adolescents (12–13 year olds) for POS visitation and physical activity. Sleepstraat Ghent.

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Aesthetics. Many adolescents mentioned aesthetics of the POS to be important to visit a POS and to be active. The most important factor was the presence of nature and green. One 15-year-old girl said: "*I usually come here to jog, and when a place is green and open it motivates to be active. This is one of the reasons why I come to this park*". (Girl 1, 15 years). Many participants indicated that these green settings encourage them to be active. A few adolescents also indicated that fresh air (produced by the trees in parks), singing of birds and insects they could examine, encouraged POS visitation.

It was indicated by a few participants that more colours in POS would be good. Graffiti was only accepted on a special graffiti wall or as a beautiful wall- or ground painting, not as "tags" (Fig 5). Few participants said they liked historical elements in POS as a landmark (e.g., to meet up at the big statue in the middle of the square). Furthermore, these historical elements (such as statues and old buildings) were liked because they illustrate the historical background of the city (Fig 6). A few adolescents said they liked to go to POS for rest and quietness, and other adolescents reported that loud music would discourage them from visiting the POS.

Upkeep. The cleanliness and upkeep of the POS were important for encouraging visitation and physical activity in the POS. Many participants mentioned garbage lying around (as a result of a lack of bins or full bins) (Fig 7), broken glass on the ground and illegal dumping of litter as factors that would discourage their visitation and physical activity. This is illustrated by a quote from a 14-year-old boy: "*The refuse collectors should come more often to clean the park, now there is garbage everywhere. We come here often for a picnic and there is only one bin around here and it is always full. And because it is always full everybody just throws garbage on the ground. The bin should be emptied more frequently and they should put a second bin somewhere over here.*" (Boy 10, 14 years).

The maintenance of the facilities and amenities was also mentioned by some participants as important for visiting the POS and being active. Maintenance of the surface of the playgrounds and sport fields was also mentioned by some participants. A playground or sport field encouraged physical activity when the surface was made of appropriate materials (e.g., no sand or concrete on a soccer field), there were no dangerous objects lying around (e.g., glass or stones) and when playing surfaces were even (no cracks). A 12-year-old boy mentioned: "*Although there*

Fig 4. Sport fields were mostly pointed out as important by boys to visit and be active. Kielpark Antwerp.

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are soccer goals here, we don't play soccer here. There is sand here and it is not easy to play soccer on sand and there is garbage and glass on the soccer field and that is dangerous. Although there are no goals on the grass and it is located on a slope, we prefer to play on the grass since it is better maintained and there is no glass." (Boy 2, 12 years).

Physical aspects of safety. Physical aspects that negatively affected adolescents' feelings of safety were insufficient lightning, poor maintenance of the facilities, too much traffic near the POS, and secluded areas or paths. Safe facilities for young children was also mentioned to be important by a few participants because many adolescents go to POS with their (younger) siblings. For example, one 12-year-old girl said: "*These stairs (with very high steps) here are too dangerous for young children. I think that it is important because I don't like it when my younger siblings get hurt."* (Girl 2, 12 years).

Secluded areas and paths were perceived unsafe for a few participants and were often avoided by adolescents. For example, a 13-year-old girl mentioned: *"I like it here because it is a large and open space and you can see everything that is going on. It is good if there are some trees*

Fig 5. Ground paintings were perceived as attractive, unwanted graffiti as not attractive for visiting a POS. Bethlehemplein, Brussels and Rabotpark Ghent.

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Fig 6. Historical elements and statues were perceived by some participants as attractive to visit a POS. Prinsenhofplein, Ghent.

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but not too much otherwise it is too secluded." (Girl 6, 13 years). Similarly, a 14-year-old girl stated: *"[. . .] it is open here, if something would happen, there will always be someone who would see it and come and help."* (Girl 3, 14 years). The absence of sufficient road crossings,

Fig 7. Garbage lying around was perceived to be unsupportive to visit a POS. Rabotpark, Ghent.

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traffic lights and cycle paths around the POS contributed to feeling unsafe in traffic and discouraged POS visitation: *"When I come out of the skate park, it is dangerous to cross the street here, it is a street with lots of traffic. There are some road crossings here but it would be better and safer if there were more. I think the cars would pay more attention."* (Boy 9, 14 years).

Policy. Activities that were sporadically organized at the POS were perceived as positive for encouraging physical activity. These organized activities made it possible for adolescents to engage in a variety of activities such as badminton, tennis, and bouncy castle with equipment they do not have or cannot afford themselves and was perceived as a trigger to visit a POS and be active. A secluded area for dogs was perceived as positive by a few participants (i.e., non-dog-owners) whereas others preferred to let their dog walk around off-leash in the POS.

Part 2: Social environment

Social network. When asked with whom participants visited the POS, 71% indicated that they usually visited it with friends, 46% with family, 14% said they usually visited the POS

alone and an additional 3% with an organization such as scouts. Almost all participants attached great importance on the places where their friends and family (especially siblings) were or wanted to go. When asked why they would go to a specific POS, many participants answered: *"Because this is where my friends are."* The importance of friends was illustrated by a quote from a 12-year-old boy: *"I find it really important that my friends are here, because every time I come here alone it is so boring and then I have to wait and wait till my friends come."* (Boy 3, 12 years). A 15-year-old girl stated: *"I often run into people I know here, that really attracts me to come here. Depending on who I encounter, I may do something active or not."* (Girl 5, 15 years).

Social contact in the POS was also mentioned by some participants to be important for visiting a POS and to be active. Almost all participants indicated that when they knew many people in the neighbourhood they were more likely to visit a POS as they felt safer. More youth in the POS to play with, was also perceived as positive by almost all participants. Therefore, POS not often used by adolescents (e.g., a small playground with features for small children, mostly used by mothers with young kids) were considered less attractive to visit and to be active.

Other users. The behaviour of other users (particularly adolescents older than 16 years) was something mentioned by almost all participants and it appeared to be a deterrent for visiting and being active in a POS. For example, *"I like to play soccer but sometimes when we are playing there are older kids who come here and they say we have to leave because it is their soccer field and that is not nice. . . or sometimes they take our ball and throw it away. So when there are older children here we go to another park with a soccer field so we can still play soccer."* (Boy 5, 12 years).

Few adolescents mentioned that they would prefer not to go to places where there may be lots of people of a certain ethnicity, in order to avoid conflicts. *"One week ago there were some Bulgarian kids who wanted to play with us, but we said no and then it ended up in a fight. . . . We don't like to play together because lots of them use drugs and smoke."* (Boy 6, 13 years). However, another participant mentioned that the presence of people with different nationalities in a POS attracts her to go there. Some participants also mentioned that too many people in a POS would keep them from being physically active, implying that POS have to be large enough to provide enough space for everyone.

Social aspects of Safety. Safety is an issue that is linked to all other factors of the social environment and it was mentioned by all participants in some way. The feeling of safety was a very important factor for visiting a POS, but of less importance for the activity level of the participants. Feelings of safety were most affected by the presence of undesirable POS users. People "acting weird", using drugs or drinking, involved in criminal affairs or harassing others (gangs) and homeless people discouraged almost all adolescents to visit or stay at a POS. *"I think it is a bit scary when there are people lying on the ground with booze. I don't know why, it is just a feeling I have. [. . .] There are also sometimes people doing drugs here. This is why I would not come here in the evening and why I would make a detour when I am riding my bike instead of going through the park."* (Girl 4, 15 years). Some participants mentioned a previous incident with an undesirable POS user that made them leave the POS and in some cases they indicated never using the POS again. "*We often met up here in the park with friends, but one time there were two men bothering us. We just took our stuff and went to my friend's garden. Now we never go to that park again."* (Girl 4, 15 years).

Participants seemed to be most affected by the undesirable users when there was actual interaction. *"There are often people doing drugs over there, but that has no influence on me, it doesn't bother me. However, when there are gangs hanging around it does bother me to come here and to be active. Because they sometimes harass us, or most of the time, the girls."* (Boy 19, 14 years). Feeling unsafe in the presence of undesirable users was mostly mentioned by girls.

The presence of these undesirable users made the participants feel unsafe, however, for a few participants these feelings of insecurity were minimized when women with children or people they knew were in the POS.

The idea of being alone in a POS in the evening or at night was scary for some of the participants: *"I don't think it is nice here in the evening, during the day there are many children and people walking around, but I think that in the evening it gets really quiet here and that doesn't give me a safe feeling . . . When there are people and children around me I feel more at ease, it is good to know that there is someone to go to if I would have a problem . . . At night there are people sitting here on the benches and that is scary."* (Girl 4, 15 years).

Some adolescents pointed out that when they trusted the other users in the POS, when people got along well and were willing to help, they felt safer, and therefore used the POS more often.

Parents. Parents still play an important role in adolescents' decisions concerning POS visitation. A few of the participants said they go to one specific POS just because they were used to go there with their parents when they were younger. Some participants had to ask permission before going to a POS and were not allowed to go to a POS that was located too far away from home or where parents perceived it to be unsafe: *"We almost never go to the other place because we heard bad things happen there and there are often groups of men hanging around, sometimes taking drugs. That is why our parents do not allow us to go there. Only when it is totally empty we can go there together with our family."* (Boy 7, 12 years).

Privacy. Privacy was an important issue for a few participants. Some of them especially went to POS to have some time alone, away from their parents. POS offer a good alternative (compared to sitting at home) for adolescents because at home it often gets crowded: *"At home we are always together and our house is not that big and it is always a bit crowded. When I come to this POS, there are more people here but it is less busy than at home."* (Girl 5, 15 years). Few of the participants indicated that small secluded places are good when they want to be in a quiet place or alone with friends.

Modelling. Friends asking to hang out or do something together contributed to being active for almost all of the participants. The activity level of parents was less important. *"When someone starts playing with the ball, everybody gets active"* (Girl 6, 13 years) and *"My friends often ask to do something, today we went swimming. And when we go to the playground there are often other boys to play with and then we can choose whether we play together or not. . . So when I come here with friends we can ask others to join and when I am alone I can come here and make new friends."* (Boy 3, 12 years). Active use of POS by others, was something that was perceived as supportive by many adolescents for the atmosphere and to be active. *"The park near my house is always empty and when I look out the window I want to see people playing, running, moving . . . and then I would want to go out immediately and play along."* (Girl 10, 14 years).

Discussion

The objective of this study was to investigate the physical and social characteristics of POS in low SES neighbourhoods that affect adolescents' POS visitation and physical activity in POS. Walk-along interviews were used to obtain context-specific and detailed information. The results show that there are different aspects of the physical and social environment that affect visitation and physical activity in a POS. Moreover, there was a substantial overlap in factors that affect visitation and physical activity in POS. Adolescents' (active) use of POS was affected by the following aspects of the physical environment: accessibility and location, features, aesthetics, upkeep, safety and policy. The aspects of the social environment that affected adolescents' (active) use included the social network, presence of other users, safety, parents, privacy and modelling.

During the analysis of the interviews it became clear that it is almost impossible to completely separate the physical and social environmental factors that affect (active) use of POS. This is supported by the ecological model of health behaviour, stating that several levels influence physical activity [15], and that interactions exist between the different levels. For example, some participants indicated that they thought it was important to have facilities for the young and old (= physical environment) so that they can visit a POS with their siblings, parents and grandparents (= social environment). The interplay between these environments may exist in two directions: strengthen a positive or negative impact or counteract the impact. For example, the impact of a positive physical environment (e.g., a POS with well-maintained and age-appropriate features) can be reinforced with a positive social environment (e.g., lots of other adolescents to play with), or the impact of a positive physical environment can be counteracted when the social environment is unsupportive (e.g., adolescents feel unsafe because of the presence of undesirable users). Whether physical or social environmental characteristics dominate the decision to visit or to be active in a POS appeared to be strongly dependent on personal experiences, beliefs and the specific purpose of visiting a POS. This indicates that researchers should consider both physical and social factors of POS to generate a more comprehensive view on the characteristics that influence whether or not adolescents visit and use a POS for physical activity.

Our results indicate that the social environment of POS may play a more important role than the physical environment. The presence of other adolescents and friends encouraged POS visitation and physical activity. This was also found in previous studies with younger adolescents in the US (9–13 years and 12–14 years old [65, 66]). Consistent with previous literature, the presence of other adolescents and friends and family who are physically active in a POS encouraged adolescents to be active in POS themselves [40, 67]. The presence of others (whether or not active) appeared more important than physical characteristics. This indicates that POS with a positive social and physical environment should be created and that exclusively investing in the physical attributes of POS may not be sufficient. Only a few participants mentioned organized activities in POS, possibly indicating that there are not many activities organized in the POS where the interviews took place. However, organized activities offer a good opportunity to create a supportive social environment and to encourage low SES youth to be active.

Our findings showed that accessibility (POS located close to home and easy accessible by foot, bike and public transport) was important for choosing a POS to go to, due to limited independent mobility of adolescents compared to adults. However, almost all participants mentioned that specific features (e.g., sport facilities) and social factors (e.g., friends) could encourage them to visit a POS located further away. This finding could possibly explain the inconsistencies found in previous literature concerning the relationship between accessibility of POS and adolescents' physical activity [25, 28–32]. Previous research has investigated the POS closest to the adolescents' home assuming that these are the most frequently used POS. However, this study showed that POS located further, with a positive physical and social environment may also be used. Although accessibility was not mentioned to affect physical activity directly, a POS that is easily accessible by foot or bike can contribute to overall physical activity. Our results revealed that many adolescents used active transportation to travel to a POS. This is consistent with previous research which showed that active transportation was used most frequently among youth to travel to a park [17, 68]. Moreover, adolescents' active transportation is positively associated with daily physical activity [37]. Creating easy accessible and attractive POS can lead to higher amounts of active transportation to POS among youth and thereby increase overall physical activity. Thus, total physical activity levels can be increased, even when adolescents visit a POS to engage in sitting activities.

The most frequently mentioned modifiable physical factors for visiting and active use of a POS for both boys and girls were natural features, playgrounds (mostly younger participants) and sport fields. However, the use of these sport fields and playgrounds may depend on the type of sport and play facilities that are present, as some participants did not have the right equipment to use these facilities (e.g., badminton racquets). Some physical attributes that affected feelings of safety were linked to fear of getting hurt (e.g., poor maintenance of the facilities). This was mostly mentioned by girls which is consistent with previous literature [38, 69]. In our study, participants indicated road safety (e.g., insufficient pedestrian crossings) was important for POS visitation. In the review of Carver et al., no association was found between road safety and physical activity in adolescents [70]. Fear from crime (for example caused by secluded paths) was also mentioned, comparable with the results of the qualitative study conducted by Ries et al. (2008) [38].

The social aspects of safety that affected adolescents visiting and being active in a POS were undesirable users, number of other users and safety at night. The review of Carver et al. (2008), on the influence of neighbourhood safety on physical activity in children (7–16 years), revealed no association between stranger danger and physical activity [70]. This is in line with our finding that undesirable users discouraged visitation, but were not mentioned to affect physical activity in POS. Additionally, when mothers with children were present in a POS the negative impact of the undesirable users could be counteracted, which indicates that a POS with facilities for all ages can provide an environment where adolescents feel more safe.

Practical Implications

For youth living in low SES neighbourhoods, POS can provide opportunities to be active outdoors. Urban planners and governments should try to create neighbourhoods with a positive social and physical environment. Possible ways to create a supportive social environment are: organizing events and activities in POS, providing sufficient lighting and no secluded places to increase social control. POS should be easily accessible and facilities that require (expensive) additional equipment (such as badminton racquets) should not be installed unless appropriate equipment is provided. Features for all ages are important for adolescents, such that they can visit a POS with friends and family. When designing a POS, both natural elements and sports- and play features appropriate for multiple age groups should be included. A variety of features that provide opportunities for different types of physical and social activities together with additional amenities (such as toilets) should be incorporated in new POS. Additionally, we found that adolescents also attach importance to POS with lots of colours (e.g., wall/ground paintings) and landmarks (e.g., a statue). When renovating existing POS, monuments and colours can easily be added. Furthermore, more attention should be paid by the city government to the maintenance of the features and surfaces of sport fields as this was a key factor for physical activity in POS (mainly for boys).

Strengths and Limitations

The current study has some limitations that should be taken into account. First, this study tried to include all kinds of POS like vacant lots, parks, squares, playgrounds, streets and parking lots. However, interviews were only conducted in parks, skate parks, squares and sport fields/playgrounds because no adolescents were found in other locations (vacant lots, parking lots, streets). This possibly indicates that parks, skate parks, sport fields/playgrounds and squares are the POS that are used most frequently by adolescents in Belgian cities. In addition, the results were not analysed separately for each type of POS, therefore, it was not possible to determine if differences were observed for these different types of POS. Another limitation is that

this research only focused on urban POS, and future research should include both urban and rural settings to obtain a more complete overview. In addition, the interviews were only conducted in neutral to good weather (i.e., not raining), and other characteristics of POS may be important when the weather is poor (i.e., in winter months). Further, due to the qualitative character of the research, it was not possible to define which aspect of the POS was most decisive for adolescents to visit POS or for physical activity in POS.

Most previous studies have investigated the attributes of the POS closest to the adolescents' home assuming that these are the most frequently used POS. However, adolescents may visit other places and, therefore, it is important to investigate the environment that is actually used by the adolescents. This problem is known as the Modifiable Areal Unit Problem (MAUP) [71]. A strength of this study is that participants were interviewed in POS they frequently visited as well as POS they did not use. This way MAUP was avoided. Another strength of this study is the methodology used. When indoor sitting interviews are used, it is often difficult for the participants to recall specific details or perceptions of the environment. The walk-along interviews provided in-depth and context-specific information of a POS and observations of the participant whilst in the POS. This paper provides a detailed picture of all characteristics important for adolescents living in low SES neighbourhoods for visiting and being active in POS. Additionally, we examined the interplay between the physical and social environment. Future research on the physical environment should take the social environment and the interactions between the physical and social environment into account.

Conclusion

This research revealed that both physical and social characteristics of POS may affect adolescents' POS visitation and physical activity. Moreover, it is the combination of multiple factors that affect adolescents' behaviour in POS and social factors are often more influential. Therefore, it is important for designers, urban planners and researchers to focus on physical as well as social characteristics of POS. Our findings emphasize that the combination of multiple physical as well as social environmental characteristics of POS will define the attractiveness of a POS to visit and to be active. This qualitative study is a good basis for further quantitative research to examine the most important characteristics of POS, in order to create a supportive environment for adolescents to be physically active.

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Author Contributions

Conceived and designed the experiments: LVH BD DVD IDB JV JVC. Performed the experiments: LVH. Analyzed the data: LVH JVC. Wrote the paper: LVH BD DVD IDB JV JVC.

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CHAPTER 4

CRITICAL ENVIRONMENTAL CHARACTERISTICS OF PUBLIC OPEN SPACES RELATED TO ADOLESCENTS' PUBLIC OPEN SPACE VISITATION AND PHYSICAL ACTIVITY

CHAPTER 4.1.

PARK CHARACTERISTICS PREFERRED FOR ADOLESCENT PARK VISITATION AND PHYSICAL ACTIVITY: A CHOICE-BASED CONJOINT ANALYSIS USING MANIPULATED PHOTOGRAPHS

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PARK CHARACTERISTICS PREFERRED FOR ADOLESCENT PARK VISITATION AND PHYSICAL ACTIVITY: A CHOICE-BASED CONJOINT ANALYSIS USING MANIPULATED PHOTOGRAPHS

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ABSTRACT

Background: Creating an environment supportive for physical activity could be a valuable strategy to increase physical activity at the population level. The purpose of this study was to understand the relative importance of park characteristics for park visitation and park-based physical activity among adolescents, using manipulated photographs of parks.

Methods: Participants (n=1197) aged 13.4 ± 1.3 years (55.4% girls) were asked to perform two sets of ten choice-based conjoint tasks. For each choice task, a choice had to be made between two photographs of a park where ten characteristics were manipulated: naturalness, upkeep, the presence of walking paths, outdoor fitness equipment/playground, sport field, benches, drinking fountain, peers, mother with children and homeless person. In the first set of choice tasks participants had to select the park most inviting for visitation, in the second, they had to select the park most inviting for physical activity. Hierarchical Bayes Estimations were used to calculate (1) average utilities that represent the desirability of each level within a characteristic and (2) importance scores which reflect the effect each park characteristic had on the choice.

Results: The results indicate that among the studied characteristics, park upkeep was the most important characteristic for park visitation and for park-based physical activity followed by the presence of playground/outdoor fitness equipment and sport fields.

Conclusions: Policymakers should ensure that parks are well maintained, have sport fields and outdoor fitness equipment. Evaluation of such initiatives can confirm whether these park characteristics will influence actual adolescent park visitation and park-based physical activity.

Key words: Active living, recreation, public open spaces, park design, adolescence

BACKGROUND

Worldwide, the prevalence of overweight and obesity among adolescents rises continuously and overweight or obese adolescents are more likely to develop non communicable diseases such as type 2 diabetes and cardiovascular diseases [1, 2]. Sufficient physical activity can prevent overweight and obesity [3] and has been shown to enhance adolescent health [4-6]. It is recommended that adolescents engage in 60 minutes of moderate-to-vigorous intensity physical activity (MVPA) daily in order to obtain these health benefits [7]. However, worldwide almost half of all adolescents do not meet these guidelines [8-10]. Moreover, there seems to be a steep decline in physical activity levels during the transition from childhood to adolescence [11] and these physical activity habits tend to track into adulthood (i.e. lower physical activity levels during adolescence can predict lower adult physical activity levels) [12]. Therefore it is important to promote adolescents' physical activity at the population level.

Socio-ecological models of health behaviour have emphasized the importance of the environment for physical activity [13]. Creating an environment that is supportive and inviting for physical activity could be a valuable strategy to increase physical activity levels at the population level. It has been shown that parks are settings within the environment that are suitable for physical activity [14]. Parks have been defined by the International Federation of Parks and Recreation Administration as: "open space areas, mostly dominated by vegetation and water, and generally reserved for public use. Parks are mostly larger, but can also have the shape of smaller pocket parks" [15]. Previous research has demonstrated that adolescents living closer to parks perform more total leisure time- and park-based physical activity [16, 17]. Moreover, parks are valuable and accessible places where people can socialize, experience nature and relax [18]. Especially for adolescents, neighbourhood parks can be important, as from the age of twelve, adolescents gain more independent mobility, compared to younger children, allowing them to travel to local destinations without adult supervision [19, 20]. Furthermore, parks can be a destination to visit by foot or bike [20, 21] and therefore have the potential to increase physical activity through active travel even if park users engage in sedentary behaviours after arriving at the park. Therefore research to better understand how to promote park visitation and park-based physical activity is needed.

Worldwide, 54% of people currently live in urban areas and this number is expected to rise in the future, which will result in the expansion and densification of cities [22]. Within these cities, the amount of public and private green spaces is expected to decrease [23]. Haaland et al. (2015) proposed several strategies to ensure green space provision in densifying cities, such as providing green space on redeveloped sites and increasing the quality of existing green spaces [23]. In order to increase the quality of green spaces and parks, it is important to understand the most important park characteristics

related to park visitation and park-based physical activity. Additionally, urban planners and policy makers should be informed which characteristics to prioritize, as often there is a lack of funding for total park renovations.

Previous research using qualitative methods has revealed several aspects of parks to be associated with adolescent park visitation and park-based physical activity, such as the presence of nature [24], well maintained facilities [25], sport and play facilities [26], large open spaces [26] and attractive scenery [26]. Additionally, quantitative studies have confirmed associations between park-based physical activity and activity settings (e.g., playgrounds, basketball courts, pool and water features) [27, 28], greenness [29] and other features such as a skate parks, walking paths, picnic tables and toilets [30]. However, experimental studies are needed in order to inform policies about which park characteristics are causally related to adolescent physical activity [31].

Some natural experiments have been conducted in parks. However, natural experiments are still scarce [32]. A natural experiment examining park renovations in two US parks revealed that the park renovations (i.e. renovation of playfields for basketball and soccer, new fencing, landscaping, lighting, picnic benches, new soccer goals, a walkway around the field) significantly increased park visitation and physical activity levels at the playfields [33] and a paper on a natural experiment conducted in Australia indicated that the improvement of park features (i.e. installation of a walking path, fenced dog off-leash area, landscaping and a modest playground) led to increases in the number of park users and physical activity levels [34]. However, such natural experiments are difficult to conduct because of organisational and financial challenges [35].

An alternative and cost-effective method to examine which park characteristics are most important to attract adolescents to visit and be physically active in parks is the use of virtual experiments (i.e. where virtual environmental changes are examined without actual changing the real park environment). Choice based conjoint (CBC) analysis is often used in virtual experiments [36-38]. CBC makes it possible to examine how people value different characteristics (e.g. park upkeep) of a product (e.g. a park) and to understand which characteristics are the most influential on participants' preferences. Hence, CBC analysis provides information that can help decision making about which park characteristics to prioritize during park development/renovations with limited financial resources. Furthermore, within CBC analysis it is possible to systematically vary specific park characteristics (which is often not possible in park renewal projects), control other environmental characteristics (such as the weather) and present the studied product (parks in our case), in different formats such as written descriptions, photographs, or videos [39].

Virtual experimental studies using CBC analysis have been conducted to examine older adults' preferences for environmental park characteristics in the UK [36, 38] and to identify the relative importance of park features for adolescent park visitation in Australia [40]. These studies revealed that for older adults, nuisance (i.e. presence of youngsters hanging around, dog fouling, signs of vandalism), facilities (i.e. the presence of café's, toilets) and the presence of trees and plants were the most important park characteristics [36, 38], whereas for adolescent park visitation, slides were the most important park characteristic followed by absence of rubbish and the presence of swings [40]. However, these three studies used a written description of the park characteristics, which implies that the participants had to imagine these park characteristics. This may have led to different interpretations compared to responses to photographed characteristics [41]. Responses to colour digital photographs have shown good validity in relation to on-site responses [41-43]. CBC analysis with manipulated photographs has previously been used to define the most important characteristics of streets for walking and cycling among children, adults and older adults [44-48].

The purpose of this study was to examine the relative importance of specific park characteristics on park visitation and park-based physical activity among adolescents, using CBC analysis with manipulated photographs of parks. The results of this study will inform policy makers and urban planners on which characteristics to prioritize in park renovation projects, ensuring the right characteristics are present in parks as often there is a lack of funding for total park renovations.

METHODS

PARTICIPANT AND SCHOOL RECRUITMENT

Participants were recruited from secondary schools and were asked to complete an online questionnaire and two sets of ten choice tasks with manipulated photographs. First, 103 schools (located within a feasible distance of the researchers home/university) in the province Flemish-Brabant (Flanders) were selected and asked to participate in the study (via email and one week later by telephone). 63 schools did not respond to the emails or telephone calls and thirty schools declined participation. The main reasons for not participating were: too many requests for research (n=11), not interested (n=10) and no time (n=9). Ten schools near Brussels were willing to participate (response rate=9.7%) and were asked to select at least two classes from grade one to grade four (ages 12-16). The number of classes that were selected to participate ranged from 3 to 15 per school and the number of adolescents per class ranged from 6 to 24. In total, 1335 adolescents were invited to participate in the study. Participants had to be between 12 and 16 years old and healthy in order to be included in the study. A priori power analyses were performed using Sawtooth Software, Inc. 2017© and indicated

that 300 participants were sufficient. However, this study was nested within a larger study which required more participants.

STUDY PROTOCOL

Schools distributed a plain language statement to parents 2-4 days before the data collection. This included a form which they could use to inform the school and researchers they did not give permission for their child to participate in the study (a passive consent form). Parents who did not return the form, gave their child permission to participate in the study. Active consent was obtained from the adolescents. This approach was selected because adolescents had to fill in a questionnaire on a non-sensitive topic, and because the questionnaire was anonymous. This consent procedure and the research protocol for minors was approved by the medical ethics committee of the University Hospital of Ghent University (2016/0284) referring to the privacy act of December 8th, 2012 on the protection of privacy in relation to the processing of personal data [49]. One researcher (LVH) visited each class between September and November 2016. A slideshow presentation explained the purpose of the study, showed an example of the choice task and presented an overview of all manipulated park characteristics to ensure that participants clearly understood the park characteristics present in the photographs. Students were asked to fill out an online questionnaire with demographic questions, followed by two sets of ten choice tasks. On average it took 24 minutes to complete the questionnaire and the two sets of choice tasks.

DEVELOPMENT OF THE PHOTOGRAPHS

Before data collection, 6912 photographs of park characteristics were developed and manipulated on ten characteristics with multiple levels using Adobe Photoshop© software. These characteristics were selected, based on previous research [26] and literature [27, 30, 50-53] (Table 1 and Figure 1). For each characteristic, different levels were determined, for example the maintenance of the park was depicted in three levels: poor, moderate or good. All photographs depicted the same park under fine weather conditions and differed in at least one manipulated level. After the development of the photographs and questionnaire, these were pretested in a group of adolescents (n=14, 11-16 years, 13.1±1.6, 64.3% girls). The adolescents received a brief explanation about the study (similar to the explanation that was given to the participants) after which each question was read out loud by the researcher and clarity was discussed. All park characteristics in the photographs were discussed in group. After this pre-test, small adjustments were made to the questionnaire and the photographs to make it more understandable for this age group and to ensure the photographs were perceived by the adolescents as intended by the researchers.

Table 1: Characteristics manipulated in the photographs

Characteristic	**Levels**
Naturalness: Plants and trees	Some plants and trees present
	Lots of plants and trees present
Walking paths	No walking paths present
	Unpaved walking paths present
	Paved walking paths present
Upkeep	Poor maintenance (graffiti, trash, poorly maintained grass field)
	Moderate maintenance (no graffiti, some trash, moderately maintained grass field)
	Good maintenance (no graffiti, no trash, good maintained grass field)
Outdoor fitness equipment/Playground	No playground present
	Playground for small children present
	Outdoor fitness equipment present
	Outdoor fitness equipment and playground for small children present
Sport field	No soccer/basketball field present
	Soccer/basketball field present
Benches	No benches present
	Benches present
Drinking fountain	No drinking fountain present
	Drinking fountain present
Peers	No other adolescents present in the park
	Adolescents present in the park, sitting
	Adolescents present in the park, playing soccer
Mother with a child	No mother with a child present
	Mother with a child present
Homeless person	Homeless person present
	No homeless person present

Legend

1. Peers
2. Sportfield
3. Naturalness
4. Homeless person
5. Upkeep
6. Mother with child
7. Drinking fountain
8. Walking paths
9. Benches
10. Outdoor fitness equipment
11. Playground

Figure 1: Example of all manipulated characteristics

QUESTIONNAIRE

The web-based questionnaire was developed using Sawtooth software (Lighthouse studio 9.2.0). In the first section of the questionnaire, participants were asked to complete items concerning demographics (age and sex), school (grade, type of education), height, weight, health (i.e. are you healthy enough to be physically active e.g., walking or soccer), residence (in the outskirts of a village, in the centre of a village, in the outskirts of a city, in the city centre), highest level of parental education, nationality and ethnicity (place of birth for themselves, mother and father). A foreign origin was defined as having at least one parent born outside of the EU15 as defined by the Flemish government [54]. Additionally, socio-economic status (SES) was assessed using the six item Family Affluence Scale (FAS, which mainly reflects material SES) and the FAS score was calculated as follows: total score minus 6; FAS score 0-6 = low SES, FAS score 7-9 = medium SES, FAS score: 10-13 = high SES [55].

Park use was assessed using the following questions: frequency of visitation in the last three months (daily, 2-3 times/week, once/week; 2-3 times/month, once/month, < once/month, not visited in past 3 months), average duration of visit in the last three months (<30 minutes, 30-59 minutes, 1-2 hours, 2-3 hours, 3-4 hours, >4 hours), usual accompaniment to parks (alone, adult family members, siblings/nieces/cousins, friends, organised group, dog, other), activities usually performed in the park (sitting/laying down, standing, walking, biking, skating/BMX/roller-skating, ball sports, active games, jogging, yoga, exercising), transportation to the park (by foot, by bike/skateboard/longboard/roller-skates, by car/motorbike as a passenger or by public transportation) and time taken to walk from home to the nearest park and to the park they visit most often (1-5 minutes, 6-10 minutes, 11-20 minutes, 21-30 minutes, 30+ minutes, don't know). These questions were previously used by Veitch et al. [56]. Physical activity levels were assessed with the FPAQ (Flemish Physical activity Questionnaire) which was previously used to assess adolescents' physical activity [57-59] and has shown fair validity [60].

In the second part of the questionnaire, participants were asked to perform two sets of choice-based conjoint (CBC) tasks, each with ten individual choice tasks. Participants were presented with two photographs of a park with different combinations of levels of characteristics as presented in Figure 2 and 3. In the first set of tasks, participants indicated which park from the two displayed parks they preferred to visit (Figure 2), while in the second task, they were asked to select the park most supportive for physical activity (Figure 3). Prior to the first choice task, the following instructions were read to participants by the researcher: *"Imagine that you are going to a park during the day on the weekend. The weather is ideal, it is not too warm, not too cold, there is no wind, and it is not raining. You will see two photographs of a park. Imagine that you know both parks and they are both close to your home. Please take your time to look at the photographs, and then select the park that is most inviting to visit. In total, you will be presented with 10 tasks where you have to choose the park you*

prefer to visit. There is no right or wrong solution, we are just interested in what you consider to be the most important characteristics in a park.'' Before the second choice task, the same instructions were given. However, this time participants were asked to select the park that was most inviting to be physically active. Physical activity was described as*: "all activities except sitting and laying down, such as playing active games, walking the dog or sports such as soccer".* After each choice task in the second set of choice tasks (where they chose the park they preferred for physical activity), participants were then asked whether they would actually be active in that park (Figure 3). This extra question (further referred to as a no-choice option) was offered as it was hypothesized that participants could perceive the selected park as most inviting of both presented parks, but not inviting enough to be actually physically active in the selected park.

For each set of choice tasks, the two photographs presented were randomly selected by the Sawtooth program. Two of the ten choice tasks in each set were fixed choice tasks. For these fixed tasks, the photographs were selected in advance and were the same for all participants (i.e. participants had to complete the same choice task twice). Consequently, it was possible to examine the test retest reliability of these tasks. Furthermore, the fixed tasks were used to evaluate the validity of the model by comparing participants' responses to the fixed tasks with the responses predicted by the model.

Figure 2: Example of choice task in the first set of choice tasks

Figure 3: Example of choice task in the second set of choice tasks

DATA ANALYSES

Descriptive statistics were calculated using IBM SPSS statistics 22. Differences between included and excluded participants were calculated using independent sample t-tests and chi²-tests. All analyses on the data obtained from the CBC analysis were performed using Lighthouse Studio 9.2.0 (Sawtooth Software). CBC analysis results in two variables; importance scores and part-worth utilities.

First part-worth utilities were calculated. These represent the desirability of each level of a park characteristic and are similar to a regression coefficient. Part-worth utilities can be used to determine which level within a park characteristic is preferred. In order to present the data clearly, the part-worth utilities were zero-centered. Next, importance scores were calculated for each park characteristic using the utility scores gained from the Hierarchical Bayes analysis [39, 61]. These scores reflect the effect each park characteristic has on the choice with higher importance scores result in a higher impact on the choice. It is important to note that these importance scores represent the difference in average part-worth utilities between the least and the most preferred levels of that characteristic.

Second, 95% confidence intervals were manually calculated in Microsoft Excel 2013 to compare part-worth utilities and importances, with non-overlapping confidence intervals representing significant differences between importances and part-worth utilities within the same characteristic. The no-

choice option that was included in the second set of choice tasks (active use of parks) was taken into account in the analyses. Additionally, the validity of the model was examined by comparing the predicted answers for the fixed choice task with the actual answer given by the participants. The percentage of agreement for the two fixed tasks (one for both sets of choice tasks) is presented and represents the percentage of answers that were correctly predicted by the model.

RESULTS

From the total sample that was invited to participate (n=1335), 10 adolescents were not willing to participate, 6 did not have parental consent, 38 participants were not healthy enough to be active, and 84 participants were younger than 12 or older than 16 years. After removing these participants from the dataset, 1197 participants remained for analyses. First, test retest reliability was completed for the two sets of fixed choice tasks. This test showed good reliability with 90.4% agreement for the set of choice tasks about park visitation and 88.7% agreement for the set of choice tasks about park-based physical activity. After removing the participants who answered inconsistently on at least one set of choice tasks, 972 participants remained for analyses.

Some differences were found between participants that were included in the study (n=972) and the excluded participants (n=225): included participants were slightly younger (13.3 vs 13.6; $p<0.05$), in a lower grade at school (64.4% vs. 56.4 % in first or second grade; $p<0.05$) and had a higher parental education (77.6% vs 67.1%, $p<0.05$) compared to excluded participants. Among the included participants, more adolescents had a Belgian ethnicity (64.4% vs 57.1%; $p<0.05$), complied to the physical activity guidelines (45.7% vs 32.3%, $p<0.001$) and were member of a sport club (67.9% vs 59.8%, $p<0.05$) compared to excluded participants.

DESCRIPTIVE STATISTICS

The final sample (n = 972), was aged 13.3 ± 1.3 years, 54.0% were girls and 64.9% were in the first or second grade of the 10 secondary schools recruited. Almost all participants were born in Belgium (94.0%), but 35.6% had a foreign origin. In total, 77.6% had at least one parent with higher education. The FAS indicated that only 5.3% had a low SES, 30.9% medium SES and 63.8% high SES. Most participants lived in suburban or urban areas (89.5%), 45.7% of the participants complied with the guidelines of 60 minutes MVPA daily and 67.9% were members of a sport club. Excellent agreement was found when comparing the predicted answers for the fixed choice task with the actual answer given by the participants (98.5% for park visitation and 94.4% for park-based physical activity) (Table 2).

Table 2: Descriptive statistics of the participants (n=972)

Age (M±SD)	13.3±1.3
Girls (%)	54.0
Grade (%)	
1st	36.7
2nd	28.2
3rd	16.7
4th	18.4
Born in Belgium (%)	94.0
Other ethnicity (%)	35.6
Education parents (% at least one parent high educated)	77.6
Family affluence scale (%)	
Low	5.3
Medium	30.9
High	63.8
Living area (%)	
Rural	10.5
Suburban	57.5
Urban	32.0
Meets physical activity guidelines (%)	45.7
Member of sport club (%)	67.9
% agreement between predicted and actual choice for set 1[a]	98.5
% agreement between predicted and actual choice for set 2[a]	94.4

[a] percentage for which the model correctly predicted the actual choice made by the participants

Half of the of the participants (50.8%) reported to be regular park users in the past three months (at least 2-3 times a month) and most park visits lasted between 30 minutes and two hours (61.3%). During a park visit, participants were usually accompanied by friends (63.1%) and the most popular activities undertaken during a park visit in the past three months were walking (60.2%) and ball sports (43.4%). Most participants walked (70.6%) or biked (39.8%) to the park. More than 60% of the participants had access to a park within 10 minutes walking distance from home and 59.1% reported using the park closest to home most often (Table 3).

Table 3: Park use

Park usage in the last three months	%
Never	13.0
Less than once a month	19.1
Once a month	17.1
2-3 times a month	21.8
Once a week	12.2
2-3 times a week	10.8
Daily	6.0
Usual duration of a park visit in the last three months	
Less than 30 minutes	18.3
30-59 minutes	33.6
1-2 hours	27.7
2-3 hours	11.6
3-4 hours	4.4
More than 4 hours	4.5
Accompaniment to park in last three months (multiple answers possible)	
Friends	63.1
(Step)brother/sister/niece/nephew	35.8
Parents/grandparents/aunt/uncle	33.3
Organised group	18.1
Alone	14.5
Dog	13.2
Usual activities during park visit in last three months (multiple answers possible)	
Walking	60.2
Ball sports	43.4
Sitting/lying down	37.1
Biking	30.1
Jogging	20.4
Standing	16.1
Skating	14.8
Active games	14.7
Exercising	11.6
Yoga	0.9
Usual transportation to parks in the last three months (multiple answers possible)	
Walking	70.6
Biking	39.8
Car/moped/motorbike as a passenger	24.9
Public transportation (train, tram, bus, underground)	17.0
Skateboard/long board/scooter	10.6
Walking distance to closest park	
1-5 minutes	41.0
6-10 minutes	22.9
11-20 minutes	13.0
21-30 minutes	4.9
More than 30 minutes	8.0
I do not know	10.1
Closest park is the park that I use most often (% yes)	59.1

RELATIVE IMPORTANCE OF THE PARK CHARACTERISTICS

The relative importance of the park characteristics represents the relative magnitude of effect of each characteristic on the choice to visit a park or use it to be physically active.

PARK VISITATION

The most important park characteristic influencing the choice to visit a park was good upkeep (41.1%; 95% CI = 40.3, 41.9). The presence of a playground/outdoor fitness equipment was the second most important characteristic (16.2%; 95%CI = 15.7, 16.6) while presence of a sport field was the third most important characteristic (11.6%; 95% CI = 10.9, 12.2). These were followed by the presence of (active) peers (6.2%; 95%CI = 5.9, 6.5), absence of a homeless person (5.9%; 95% CI = 5.6, 6.1) (not significantly different from the presence of peers and the presence of walking paths), presence of (unpaved) walking paths (5.8%; 95% CI = 5.6, 5.9), lots of naturalness (4.8%; 95%CI = 4.6, 5.1), presence of a mother with a child (3.3%; 95% CI = 3.2, 3.4), the presence of benches (2.7%; 95%CI = 2.6, 2.9) and the presence of a drinking fountain (2.4%; 95% CI = 2.3, 2.5) (Figure 4).

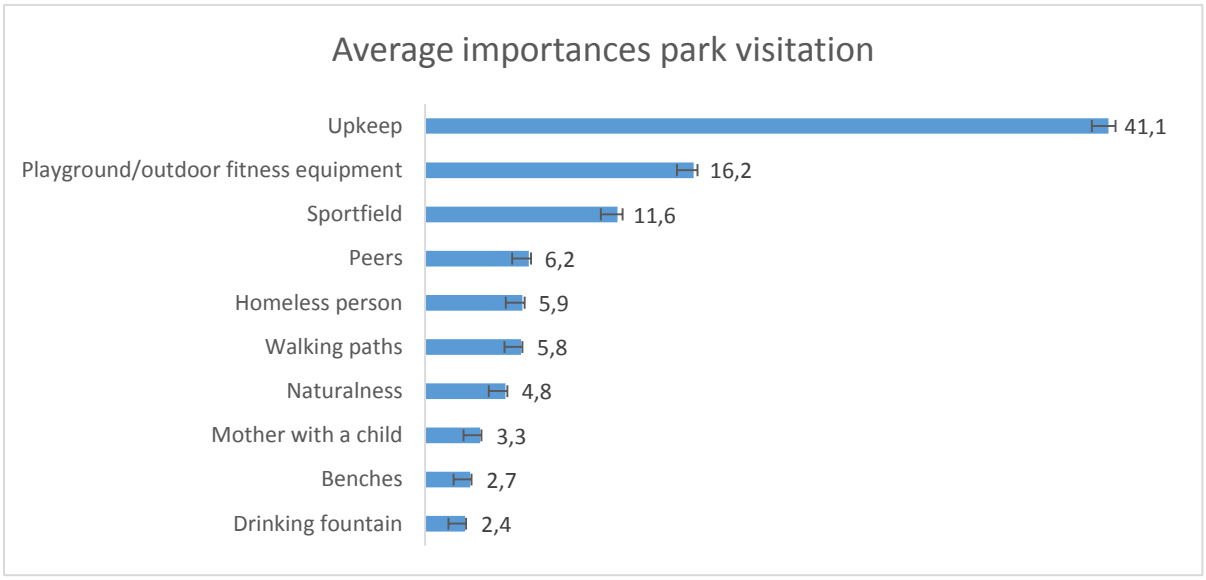

Figure 4: The relative importance of park characteristics for park visitation. The importance of the presence of peers and the presence of a homeless person did not differ significantly from each other. The importance of the presence of a homeless person and the presence of walking paths did not differ significantly from each other

PARK-BASED PHYSICAL ACTIVITY

Similar to the results for park visitation, the most important factor for physical activity was upkeep (34.3%; 95%CI = 33.5, 35.0). This was followed by the presence of playground/outdoor fitness equipment (18.4%; 95% CI = 17.8, 19.0) and the presence of a sport field (14.1%; 95% CI = 13.4, 14.7). These were followed by the presence of (active) peers (9.4%; 95% CI = 9.1, 9.7), (unpaved) walking paths (5.7%; 95% CI = 5.5, 5.9), the absence of a homeless person (5.0%; 95% CI = 4.8, 5.3), lots of naturalness in the park (4.2%; 95% CI= 4.0, 4.5), presence of benches (3.4%; 95% CI = 3.2, 3.6) and presence of a mother with a child (2.8%; 95% CI = 2.7, 3.0). Presence of a drinking fountain was the

least important factor for park-based physical activity (2.6%; 95% CI = 2.4, 2.7) (Figure 5). Data from the no-choice option revealed that for 77.4% of the choice tasks, the participants would actually be active in the selected park.

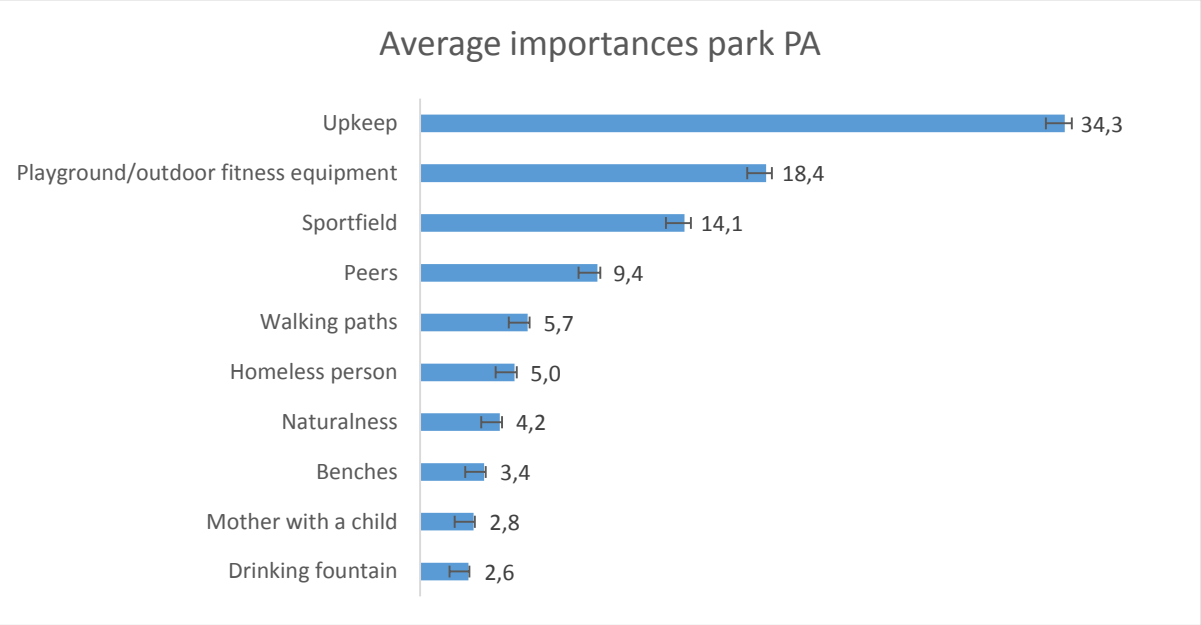

Figure 5: The relative importance of park characteristics for park-based physical activity

PART-WORTH UTILITIES

A part-worth utility represents the preference for a particular level within a park characteristic, relative to the other levels within this park characteristic. These values cannot be compared across park characteristics, only within one park characteristic.

PARK VISITATION

Part-worth utilities for each of the levels for each characteristic were significantly different from each other and the preferences were in the expected direction for the following characteristics: homeless person (a park without a homeless person was preferred), mother with a child (a park with the presence of a mother with a child was preferred), presence of peers (a park with physically active youth was preferred over a park with sedentary youth, which was preferred over a park without youth), drinking fountain (a park with a drinking fountain was preferred), benches (a park with benches was preferred), sport field (a park with a sport field was preferred), upkeep (a park with good upkeep was preferred over a park with moderate upkeep, which was preferred over a park with poor upkeep) and naturalness (a park with more trees and plants was preferred) (Figure 6).

The presence of only outdoor fitness equipment and the presence of outdoor fitness and a playground did not differ significantly, but these were preferred over a park with only a playground which was preferred over a park without playground or outdoor fitness equipment. Parks with unpaved paths

were preferred over parks with paved paths, which were preferred over parks without paths (Figure 6).

Park-based physical activity

Part-worth utilities for each of the levels for each characteristic were similar (i.e. the same levels were preferred) to the results for park visitation (see above) for following characteristics: homeless person, mother with a child, sport field, upkeep and naturalness. Part-worth utilities for each of the levels for playground/outdoor fitness equipment were significantly different from each other and the preferences were in the expected direction (a park with outdoor fitness equipment and a playground was preferred over a park with only outdoor fitness equipment, which was preferred over a park with only a playground, which was preferred over a park without playground or outdoor fitness equipment) (Figure 7).

A park with youth who were active was preferred over a park without youth, which was preferred over a park with youth who were engaged in sedentary activities. A park without benches was perceived better for physical activity than a park with benches. No significant differences were found between a park with paved and unpaved paths, but these were preferred over a park without paths. No significant differences were found between the presence or absence of a drinking fountain (Figure 7).

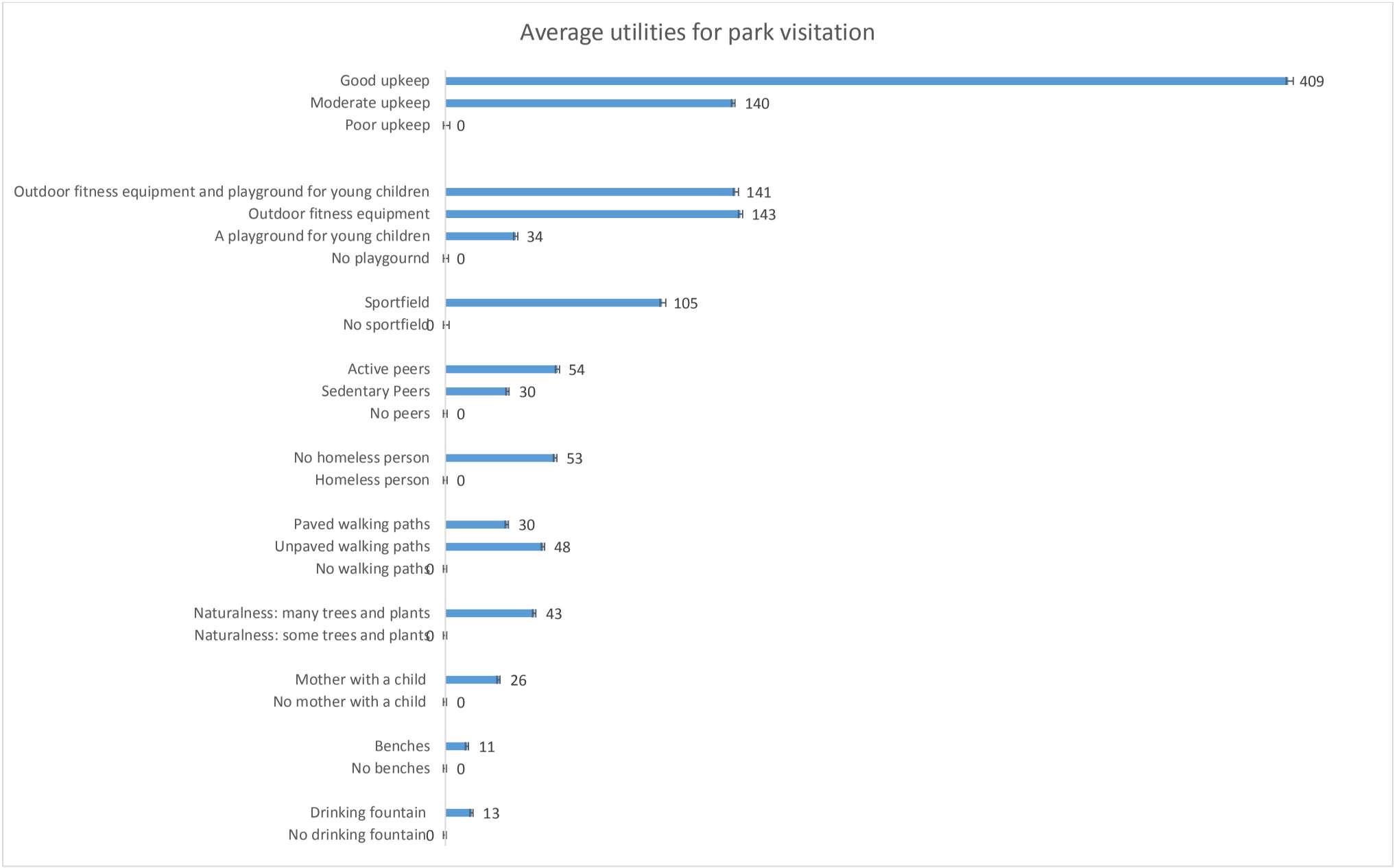

Figure 6: Average utilities park visitation

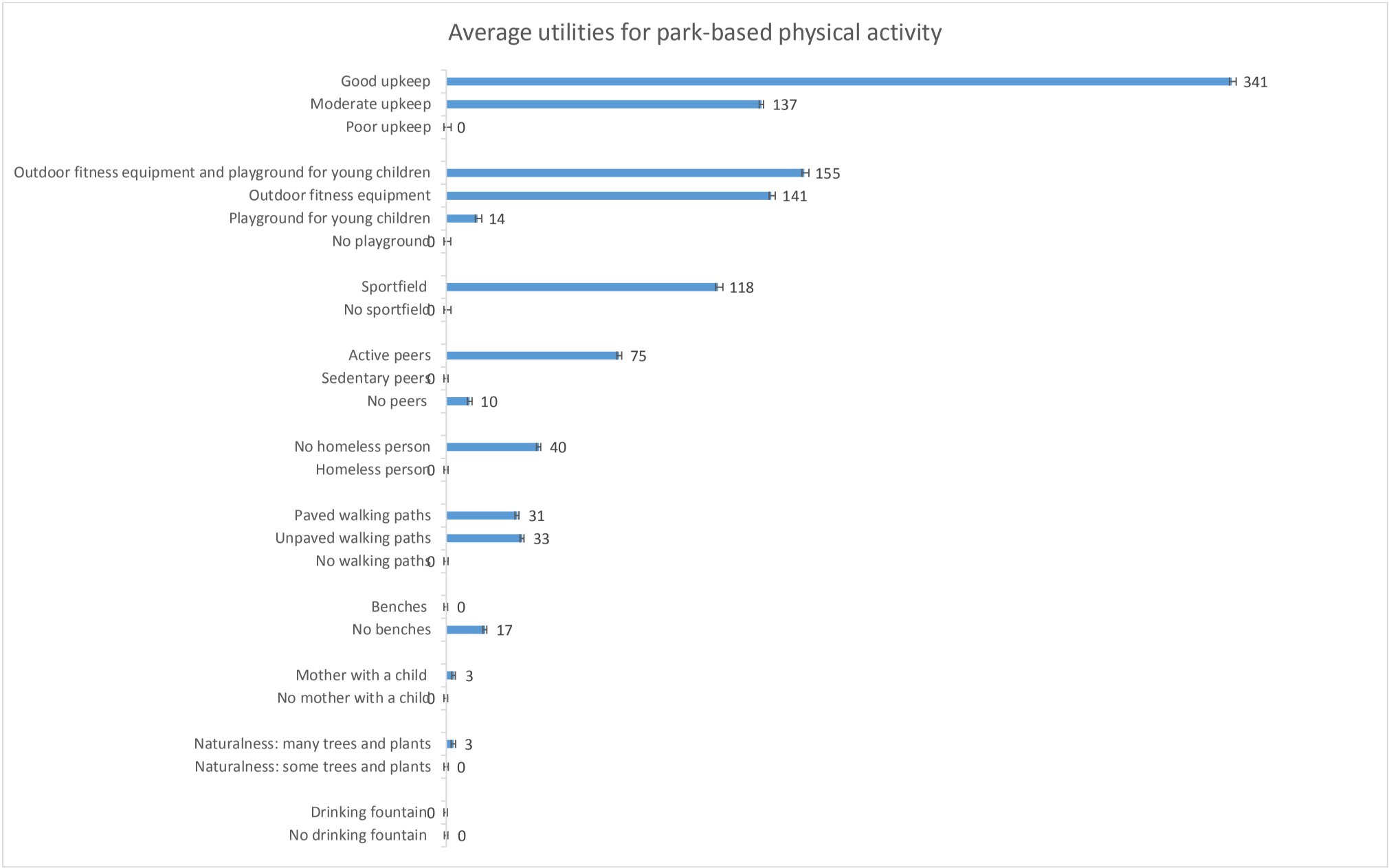

Figure 7: Average utilities of park-based physical activity

DISCUSSION

The purpose of this study was to understand the relative importance of key park characteristics for park visitation and park-based physical activity among adolescents. First, our results revealed that upkeep was the most important characteristic for park visitation and physical activity among the characteristics that were included in this study. In an Australian study [40] using a similar methodology the absence of rubbish was found to be the second most important park characteristic for adolescents' park visitation. Research from the USA also showed that parks with better maintenance had more adolescent visitors [51] and a previous qualitative study identified upkeep and maintenance as an important factor for Flemish adolescents' park visitation and park-based physical activity [26]. Upkeep may influence park visitation and park-based physical activity through the effect on perceived safety, aesthetics or through the perception of garbage being dangerous for injuries [26]. In this study, upkeep consisted of three aspects that were manipulated: presence of graffiti, presence of trash and the maintenance of the grass. Therefore, it should be noted that in the photographs used in this study, upkeep was a very noticeable characteristic which could have led to a higher importance score. Low SES neighbourhoods are characterized by urban parks with worse maintenance and upkeep compared to urban parks in high SES neighbourhoods [62, 63]. Therefore, investing in good upkeep and maintenance of parks may not only increase park visitation and park-based physical activity but also minimize differences in park quality between neighbourhoods and thus reduce social inequalities [63, 64].

A natural experiment conducted in Australia has reported significant increases in MVPA at the outdoor fitness zones and in the amount of park visitors in the outdoor fitness zone after installation of the outdoor fitness equipment and after twelve months of follow up [65]. Our results contribute to the existing literature, as this study revealed that the presence of playground/outdoor fitness equipment was the second most important characteristic for adolescent park visitation and park-based physical activity. For park visitation, no difference was found between a park with a playground and outdoor fitness equipment compared to a park with only outdoor fitness equipment. In other words, the playground did not add any additional value to the park for park visitation when outdoor fitness equipment was already present. However, if a more challenging playground would have been depicted, this may have led to different results [40] as the playground that was depicted in the photographs was designed for small children (i.e. a slide and a seesaw animal). For park-based physical activity, the presence of outdoor fitness equipment combined with a playground was perceived better than outdoor fitness equipment alone. One possible explanation for these results may be that a playground for younger children is not important when adolescents visit a park, but when they visit a

park for physical activity, a playground at the park could be more important to keep younger siblings occupied while they are physically active. This is consistent with previous qualitative research, where Flemish adolescents indicated playgrounds to be a positive feature for park visitation and physical activity and reported facilities for all age groups to be important so that adolescents who have to babysit their younger siblings can bring them to the park [26].

A park with a sport field (soccer and basketball) was preferred over a park without a sport field. This was no surprise since 40% of the participants in this study reported to have used a park for ball sports in the past three months. Moreover, this is in agreement with most previous research among adolescents [27, 56]. However, an Australian study using CBC with written descriptions of parks, reported a basketball area to be ranked at 7th place of importance (out of the 10). These differences in results may be due to other park characteristics that were included in that study (e.g. swings, BMX tracks/skate bowl), the written description instead of photographs that was used, the study sample (60% girls) and cultural differences between Australia and Belgium [40].

It has been shown that peers can influence adolescents' physical activity behaviour [66-68], park use by friends and family can predict adolescent park use [69] and qualitative research has indicated that adolescents often need peers to play together on the courts [25]. Our study showed that when adolescents go to a park for physical activity, they prefer a park where other adolescents are active over a park where no adolescents are present. These two situations (presence of active adolescents and no adolescents present) were chosen over a park where other adolescents were sitting down. This is a novel insight as previous research only investigated the presence of other adolescents [26, 52], without taking into account the activity level of the adolescents (i.e. physically active or sedentary). This result could possibly be explained by peer modelling, i.e. when adolescents see peers being sedentary/physically active they may imitate peer's behaviour. However, a systematic review concluded peer modelling not to be related to physical activity levels among adolescents (however it was noted that this could be due to measurement errors) [70]. This result implicates that parks should provide opportunities for adolescents to engage in physical activities together with peers.

Surprisingly, adolescents preferred a park without benches when visiting a park for physical activity. Previous qualitative research led to the hypothesis that a park with benches would be preferred because of the opportunity to alternate between physical and sedentary activities and to rest after being physically active [26]. A possible explanation for these findings could be that benches invite adolescents to sit rather than to engage in physical activity and are therefore perceived as deterring park-based physical activity. Contrary to expectations, participants preferred unpaved paths over paved paths for park visitation. It was hypothesized from previous research that paved paths would be

preferred, as these are suitable to ride a bike or skates [26]. This finding could be due to unpaved paths being associated with slow traffic and are therefore perceived safer, or because unpaved paths are better for jogging or have a more natural appeal.

Only few differences between park characteristics important for visitation and for physical activity were found. Sedentary peers were preferred over no peers for visitation, whereas for physical activity no peers were preferred over sedentary peers. A park with benches was preferred for visitation whereas a park without benches was preferred for physical activity. A park with a drinking fountain was preferred for visitation, whereas for physical activity there was no significant difference between presence or absence of a drinking fountain. Unpaved walking paths were preferred over paved walking paths for visitation, whereas no differences were found in preferences between paved and unpaved walking paths for physical activity. However, these small differences indicate that it is important to investigate these two outcomes separately and that some characteristics may increase park visitation, while decreasing physical activity levels in the park.

As there is often a lack of money for total renovations or new park constructions, results of the present study are of great importance for policy makers and urban planners. They may provide a way for policy makers to support decisions and set priorities concerning park renewal and design. The present research indicated that the removal of graffiti, intensive and regular maintenance and the provision of sport fields and playgrounds/outdoor fitness equipment may be a good strategy to improve the attractiveness of existing and new parks for adolescents.

STRENGTHS AND LIMITATIONS

The distinction between two outcomes (park visitation and park-based physical activity) was a major strength because these different behaviours can be influenced by different park characteristics. Another strength was the inclusion of some social characteristics such as the presence of peers, a homeless person or a mother with a child. It has been shown that social characteristics influence the attractiveness of a park and are often neglected in research concerning park characteristics. The systematic randomisation of the park characteristics within the photographs was another strength of this study which cannot be achieved using real life experiments. Additionally, by using manipulated photographs it was possible to control variation within and between environmental characteristics and standardize for other influencing factors such as the weather.

The first limitation of this study is that no actual behaviour was studied, only preference for visiting or being active in a park. However, the no–choice option revealed that in 77.4% of the choice tasks the participants reported they would actually use the park for physical activity. This result indicates a high applicability of the reported results. Additional real-life experiments are needed to examine whether

changing the most important park characteristics identified in the present study will lead to actual increases in park visitation and physical activity among adolescents. A second limitation of this study was the inclusion of only ten park characteristics. In real life, a park visitor will be influenced by more than ten characteristics. However it was not possible within this study design to include more park characteristics, as the inclusion of more park characteristics would have led to more choice tasks needed and would have increased participant burden. The characteristics included in this study were carefully selected based on previous research [26] and literature [27, 30, 50-53], however, the selection of other park characteristics (such as trees providing shade or signs concerning dogs in the parks [71]) could have led to other results. A third limitation was that by using photographs, only a small part of a park can be depicted, some characteristics are depicted more central than others, it is possible that more cognitive-based answers were given instead of emotional preferences and a different depiction of the same characteristic could have led to different results. A fourth was that, it is not possible to include park characteristics related to sound, such as quietness, and previous research has indicated quietness to be important for park visitation [26, 71]. These limitations of using photographs could be avoided in future research by using virtual reality or videos, which possibly elicit more emotional or affective relations that may be of importance. The fifth limitation was the homogeneity of the sample as more than 60% had high SES. Additionally, both questions (park visitation and park physical activity) yielded similar results with only minor (but important) differences. This could be caused by adolescents mainly using parks for (some kind of) physical activity or by participants not being able to distinguish between both concepts.

RECOMMENDATIONS FURTHER RESEARCH

Not many differences were observed for the relative importance of park characteristics for park-based physical activity compared to the characteristics important for park visitation. However, we recommend further research keeps these two behaviours separate as these behaviours may be influenced by different (combinations of) park characteristics. Future research should continue to consider the use of CBC analysis as this provides many advantages (e.g. low cost, possibility for randomisation of park characteristics) compared to traditional questionnaire research or natural experiments. However, other park characteristics that influence park visitation and physical activity could be included such as trees providing shade, signs concerning dogs in the parks, the size of the park and park access [71]. Moreover, this novel method should be elaborated and future studies should examine the possibilities of virtual reality to create a more realistic experience which participants are exposed to. Next to these virtual experiments, there is need for natural experiments to confirm the results of the virtual experiments.

CONCLUSION

We can conclude from the results of this study that parks with good upkeep and adequate playgrounds/outdoor fitness equipment and sport fields are preferred for adolescent park visitation and physical activity. Natural experiments should be conducted to confirm whether better upkeep and maintenance and the presence of sport fields and playgrounds/outdoor fitness equipment influence real-life park visitation and park-based physical activity among adolescents.

LIST OF ABBREVIATIONS

CBC: Conjoint based choice
CI: Confidence interval
EU: European Union
FAS: Family affluence scale
FPAQ: Flemish Physical Activity Questionnaire
MVPA: Moderate- to vigorous-intensity physical activity
SES: Socio-economic status

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PART 3: GENERAL DISCUSSION

This doctoral thesis aimed to (1) provide an overview of current physical activity levels among European youth, (2) gain insight into the use of public open spaces in Flanders (Belgium), (3) examine the environmental characteristics of public open spaces associated with adolescents' public open space visitation and physical activity and (4) develop an experimental study using manipulated photographs to identify the most important park characteristics inviting adolescents to visit and be physically active in parks. First an overview of the main findings is given, followed by a discussion of the results and the strengths and limitations of the included studies, finally practical implications and recommendations for further research are given.

1. SUMMARY OF THE MAIN RESEARCH FINDINGS

The **first aim** of this doctoral thesis was to provide an overview of the current physical activity levels among European youth (0-18 years). Therefore, a systematic literature review was performed (Part 2: Original Research: chapter 1.1). In line with recent trends, across all countries, boys had higher physical activity levels than girls and children (0-12 years) had higher physical activity levels than adolescents (12-18 years). Furthermore, in most European countries, less than half of the participants complied with the physical activity recommendations, regardless of the measurement method that was used. Moreover, when subjective measurement methods were used, large differences were found between European countries, ranging from 5% to 47% of the participants complying with the physical activity guidelines. Also, when minutes of moderate-to vigorous-intensity physical activity were measured using accelerometers, large variation in physical activity levels between studies was observed.

The variety in outcome measures, the diversity of measurement methods (i.e. questionnaires, accelerometers and ecological momentary assessment) and measurement properties (e.g., five different cutpoints were used to define moderate- to vigorous-intensity physical activity among children) made comparisons between studies nearly impossible. The large variation in physical activity levels may have been caused by these methodological issues, however, they could also reflect true differences between European countries. Therefore, a pan-European surveillance system including standardized methods and outcomes is needed. Such a surveillance system is essential for the development and evaluation of environmental interventions and can inform new policies and strategies to promote physical activity.

The low levels of physical activity among adolescents that were identified in chapter 1.1. (Part 2: Original Research) emphasize the need for the development of interventions and strategies to promote physical activity among adolescents. Public open spaces can be a location suitable for physical activity. Therefore, the **second aim** of this doctoral thesis was to gain insight into adolescents' use of public open spaces in Flanders (Belgium). In a first study (Part 2: Original Research: chapter 2.1), it was found that most of the observed park users were adult, male and Caucasian. Almost half of all observed park users were observed while engaged in vigorous-intensity physical activity, one in four park users was observed while engaged in moderate-intensity physical activity and one in four park users was observed while engaged in sedentary activities. The activities in which park users were observed most frequently included biking, sitting, walking and playing. Remarkably, during more than half of all observation moments, the park areas were empty. When studying the associations of temporal variables and park areas with the number of park users observed in the parks, no differences were found in the number of park users during the weekend compared to weekdays. Parks were used least often during the morning and trails were the most frequently used park area followed by grassy fields with playgrounds. Additionally, it was found that trails were the park areas used at highest estimated energy expenditure. Further research is warranted in order to confirm these preliminary findings.

A second study (Part 2: Original Research: chapter 2.2) revealed that three out of four adolescents used a public open space on the days that were included for analysis. Among the public open space users, on average 1.8 ± 1.2 public open space visits were registered per day. More than half of all public open space visits were done in the company of friends/classmates and 70% of all public open space visits was located at a public transportation stop/station. Subsequently, the most frequently mentioned reasons for public open space visitation were to wait for something/someone (e.g., train) or because friends/classmates/siblings/cousins wanted to go to that location. Participants with a non-western-European ethnicity (compared to a western-European ethnicity) and those enrolled in technical education (compared to general education) were more likely to spend time at public open spaces. Public open space visits lasted longer when adolescents were accompanied by siblings. During public open space visits, boys engaged in more minutes of moderate- to vigorous- and vigorous-intensity physical activity compared to girls.

The **third aim** of this study was to identify the environmental characteristics of public open spaces associated with adolescent public open space visitation and physical activity. A systematic literature review was performed with the aim to gain deeper insight into the specific physical characteristics of outdoor public open spaces associated with adolescents' public open space visitation and physical activity (Part 2: Original Research: Chapter 3.1). The systematic literature review focussed on qualitative and quantitative studies examining associations of public open space characteristics with public open space visitation and physical activity. The presence of walking paths, playgrounds and sport fields was positively associated with public open space visitation and physical activity whereas aesthetics and safety seemed to be less important for public open space visitation and physical activity. Additionally, the systematic literature review revealed that many different methodologies were used across studies and that the majority of the studies focused on parks (and not public open spaces in general).

Secondly, a study (Part 2: Original Research: chapter 3.2) using walk-along interviews revealed that physical environmental characteristics including accessibility and location, features, aesthetics, upkeep, safety and policy-related characteristics were important for public open space visitation and physical activity among adolescents. For example, large open fields with some trees, playgrounds and sport fields were important features for public open space visitation and physical activity. The social environmental themes that emerged from this study were social network, other users, safety, parents, privacy, and modelling. For example, participants indicated to attach great importance to the public open spaces where their friends were or wanted to go and to the possibilities for social contacts at public open spaces. On the other hand, public open spaces were also identified by the participants as places where they could have some time alone, away from their parents and were, therefore, important places for privacy.

The **fourth and last aim** of this doctoral thesis was to develop an experimental study using manipulated photographs to identify the most important park characteristics inviting adolescents to visit a park and be physically active. Therefore, a study using digital photographs and CBC analysis was performed (Part 2: Original Research: chapter 4.1). This study revealed that among adolescents, the most important park characteristics for park visitation and physical activity were maintenance, followed by the presence of playground/outdoor fitness equipment and a sport field.

2. OVERALL DISCUSSION

2.1. PHYSICAL ACTIVITY LEVELS AMONG EUROPEAN ADOLESCENTS

As highlighted in the general introduction, adolescents should engage in at least 60 minutes of moderate- to vigorous-intensity physical activity daily in order to obtain health benefits [1]. Moreover, evidence suggests that physical activity levels should be even higher to prevent clustering of cardiovascular disease risk factors [2]. Therefore, the low levels of compliance with physical activity guidelines across Europe observed in the systematic literature review in chapter 1.1 are alarming. Such low levels of compliance with physical activity guidelines have also been observed in previous research studying adolescent physical activity levels worldwide and in Europe [3-5].

The overall conclusion of the systematic literature review conducted in chapter 1.1 was that there is an urgent need for a pan-European surveillance system combining objective and self-report physical activity data. These conclusions are similar to the conclusions of a report published by the World Health Organisation on physical activity levels in Europe in 2010 [3] and a review by Ekelund et al. in 2011 [4] and indicate that not much progress has been made in the development of such a surveillance system ever since. Additionally, our review confirmed previous research that concluded that physical activity levels tend to decline in the transition from childhood to adolescence [6-8], boys tend to be more active compared to girls [8-10], and highlight the need for interventions and research in this age group.

2.2. THE USE OF PUBLIC OPEN SPACES IN FLANDERS (BELGIUM)

Public open spaces are present in almost all neighbourhoods and can be an important location for adolescents' physical activity [11]. At the start of this PhD, not much was known about the use of public open spaces in Flanders (Belgium) nor in Europe. Therefore, is was necessary to gather basic information about who uses public open spaces, which specific public open space locations are used, which activities are performed at public open spaces, who public open space users are accompanied with and when public open spaces are used.

2.2.1. WHO USES PUBLIC OPEN SPACES IN FLANDERS (BELGIUM)?

It is important to gain insight into the individual characteristics of public open space users in order to develop interventions that are tailored to subgroups with low levels of public open space use. Our studies indicated that public open spaces are more often used by lower educated adolescents and those with a non-western-European ethnicity. Boys tended to be

more active at public open spaces and with increasing age, adolescents tended to engage less in vigorous-intensity physical activity at public open spaces.

Our results indicated that parks are more often used by males across all age groups and specifically by adolescent boys compared to girls. Additionally, boys were more likely to engage in moderate- to vigorous- and vigorous-intensity physical activity at public open spaces in general. Similarly, a previous Danish study using GPS devices and accelerometers, reported that during leisure time, 11- to 16-year-old boys spent significantly more time outdoors, at sports facilities and at other outdoor locations and more time in moderate- to vigorous-intensity physical activity at sport facilities, at school grounds and at other outdoor places compared to girls [12,13]. Our study adds to this literature by including all types of public open spaces and by making a distinction between different physical activity levels. Previous research [8-10] and the review included in chapter 1.1 have shown that boys have higher overall physical activity levels compared to girls. Therefore, girls have been identified as a group at risk for physical inactivity. Our studies have shown that these gender differences are also manifested at public open spaces and highlight the need for research on how to create public open spaces attractive for adolescent girls to visit and be active at public open spaces. Currently, most of the facilities present at public open spaces are targeting competitive team sports such as basketball or soccer [14,15]. However, adolescent girls engage mainly in individual, non-competitive activities such as dancing or running or group activities with the focus on fun, such as netball [16-18].

Ethnicity has been identified as a factor associated with total physical activity levels among adolescents in a previous systematic literature review, where white adolescents had higher total physical activity levels compared to all other ethnic groups [9]. However, a more recent review concluded that evidence concerning this association was inconclusive [10]. To our knowledge, no previous research has studied the association between public open space use or physical activity at public open spaces and ethnicity. Our study using GPS devices and accelerometers (chapter 2.2), indicated that adolescents with a non-western-European ethnicity spent more time at public open spaces compared to western-European adolescents. This could indicate that different cultural habits exist concerning public open space use among adolescents or that socio-economic differences between ethnic groups lie at the base of these differences [19]. These are very important results, as non-western-European adolescents are

often hard to reach for interventions, are less attracted to traditional sport clubs [20] and are at risk for physical inactivity [9]. Our results support the development of physical activity initiatives at public open spaces in order to reach this minority population. Such initiatives, called “Neighbourhood sports” (= Buurtsport) are already being implemented in some cities and municipalities in Flanders (Belgium) [21]. These include activities organized in the local neighbourhoods (in streets, parks, squares), with the aim to create easy accessible alternatives for sport clubs and increase physical activity levels among the people living in the neighbourhood. Moreover, these neighbourhood sport initiatives are also used as a means to increase integration of minority youth into society [21].

In chapter 2.2, it was found that participants with technical education were more likely to spend time at public open spaces compared to adolescents enrolled in general education. These results are consistent with previous Australian research among adults, where park users had lower educational qualifications compared to non-park users [22]. These findings have important social relevance as people with low educational level and low SES are at risk for low levels of physical activity [23].

2.2.2. WHICH PUBLIC OPEN SPACE LOCATIONS ARE USED?

Previous research has highlighted the need for tailored interventions that take the context of physical activity into account [24]. Therefore, it was needed to identify the public open spaces that are currently used and where physical activity is accumulated. In chapter 2.2, public transportation stop/stations were identified as the public open space locations that were used most often among Flemish adolescents (71% of all public open space visits). This could indicate that Flemish adolescents often use public transportation to travel to destinations. However, the high number of public open space visits at a public transportation stop/station may have influenced our results. When the public open space visits that took place at a public transportation stop/station were not taken into account, 32.4% of public open space visits were located at streets; 18.5% at parking lots; 12.0% at squares; 11.1% at a shopping street, 10.3% at a playground or sport field, 10.2% at parks, 4.6% at a shopping centre and 0.9% at a vacant lot. Remarkably, a high number of POS visits was located at parking lots. This could have been caused by the fact that adolescents often had to wait at a parking lot for their parents to pick them up by car, as emerged from the one-on-one interviews. Furthermore, these results indicate that parks, squares and playgrounds/sport fields are not very often used.

Likewise, the parks in the observational study (chapter 2.1) were only used in 42% of the observations.

Furthermore, we found that trails and grassy areas with a playground were used by more park users compared to densely wooded areas and that trails were the park areas used at highest physical activity intensity (chapter 2.1). Additionally, the interviews in chapter 3.2 revealed that secluded areas (such as densely wooded areas) contribute to adolescents feeling unsafe, which could be an explanation for the low usage of these areas. In previous studies from the US, most park users and highest activity levels were observed on sport fields and playgrounds [14,25] (no sport fields were present in the parks included in the study in chapter 2.1). Additionally, it has been shown that activity areas such as basketball fields and soccer fields were used by more park users compared to activity areas for sports that require less participants such as tennis and demand specific sport material (e.g., a tennis racquet) [25]. These results showed that different areas within public open spaces have the ability to attract more or less visitors or elicit different activity levels.

2.2.3. WHICH ACTIVITIES ARE PERFORMED AT PUBLIC OPEN SPACES?

In chapter 2.2, a one-on-one interview was used to obtain information on the activities participants engaged in while being at public open spaces. During this interview a personalized map was used with the locations that were visited in the past days (measured with a GPS device). Hanging around was the most frequently reported activity, this was done mostly while standing, walking or sitting. This was consistent with a previous study where adolescents reported 'hanging out with friends' to be the most performed activity during leisure time [26]. Ball sports were the most frequently reported physical activity (besides walking), but these were only engaged in during 6% of the public open space visits (when all public open space visits that were located at a public transportation stop/station were not taken into account, adolescents engaged in ball sports during 9% of the public open space visits). In chapter 4.1, adolescents were asked which activities they performed during park visits in the past three months. Walking, ball sports and sitting/lying down were reported most often. However, in chapter 2.1, most park users were observed biking (38%) (probably using the park as a route to travel to another destination). Other activities that were observed were sitting (23%), walking (15%), playing (7%), or walking the dog (5%).

Overall, the results indicate that park visits are mostly spent physically active, whereas for other public open spaces this was less often the case. However, parks are not frequently used and efforts should be made to attract more people (and especially females) to parks. Furthermore, once in the park, the park itself should be inviting for physical activity.

2.2.4.WHO ARE ADOLESCENTS ACCOMPANIED WITH WHEN VISITING A PUBLIC OPEN SPACE?

The self-report data in chapter 4.1 revealed that adolescents were mostly accompanied by friends/classmates (63%), siblings (36%), adult family members (33%) an organized group (18%) or alone (14%) during park visits in the last three months. When all possible outdoor public open spaces were considered in chapter 2.2, participants reported to have been accompanied by friends/classmates in 60%, siblings in 16%, and adult family members in 16% of the visits, 16% of the visits were done alone and 3% with an organisation. Furthermore, the accompaniment by siblings at public open spaces was associated with more time at public open spaces.

2.2.5.WHEN ARE PUBLIC OPEN SPACES USED?

In order to develop tailored interventions to increase physical activity among all age groups at public open spaces, insight is needed into the periods when public open spaces are used in order to identify the periods of high or low usage. The moments when public open spaces are used by few people can be the focus of future interventions aimed at increasing public open space visitation as these offer lots of space and quietness, whereas the moments when public open spaces are currently used by many people are important for interventions that aim to increase public open space users' physical activity levels.

In our study (chapter 2.1), parks were least used in the morning. Similar results were found in a study where ten Belgian and ten US parks were observed [27]. Furthermore, in our study, park users' activity levels were higher in the morning compared to midday and to the afternoon. In the study including ten Belgian and ten US parks, most vigorously active park visitors were observed in the afternoon and in the morning compared to midday and the evening [27]. In Belgian parks, morning periods appeared to be the moments that parks are used less often, but at highest activity levels (for example by people riding their bike through the park to go to school or work), whereas parks were used most often during the afternoon but at lower activity levels. Furthermore, no differences were found for the number of park

users at weekdays compared to weekend days, whereas activity levels among males were 21% higher during weekend days (chapter 2.1).

2.2.6.CONCLUSION

To conclude, public open spaces in Flanders are mostly used by the lower educated, and those with a non-western-European ethnicity. Additionally, physical activity levels at public open spaces are higher among younger adolescents and boys. This indicates that public open spaces should be made more attractive for girls (e.g., by providing facilities for individual, non-competitive, 'fun' physical activities) and older adolescents and can provide a good location to reach minority groups (such as low SES and non-western-European adolescents) that are hard to reach and at risk for physical inactivity. Furthermore, interventions aiming to increase physical activity at public open spaces should also take into account the potential social impact of the intervention on the neighbourhood (e.g., physical activity can be used to increase social cohesion and integration of minority youth into society). Public transportation stops/stations appeared to be the most frequently used public open spaces among Flemish adolescents, however, these are less suitable for physical activity. On the other hand, parks are very suitable for physical activity, but were rarely used. This calls for interventions promoting park use and physical activity in parks among adolescents. Furthermore, urban planners should take into account the different activity levels and number of users at different public open space areas (such as trails or playgrounds). Our results showed that densely wooded park areas were not often used and were used at lower physical activity intensity compared to trails and grassy areas in parks. Therefore, we recommend to include sufficient paths through wooded areas and to avoid low shrubbery in order to create an open view. Additionally, all children within families should be involved in interventions as it was shown that adolescents spent more time at public open spaces when accompanied by their siblings. Urban planners should create public open spaces with facilities for all ages in order to facilitate public open space use accompanied by siblings and other family members. Moreover, interventions aimed at increasing physical activity levels in parks should be held during afternoons as it is most likely to reach the highest number of and the least active park users during afternoons.

2.3. ENVIRONMENTAL CHARACTERISTICS OF PUBLIC OPEN SPACES ASSOCIATED WITH ADOLESCENTS' PUBLIC OPEN SPACE VISITATION AND PHYSICAL ACTIVITY

Chapter 3.1 and 3.2 provided an extensive overview of public open space characteristics possibly associated with public open space use and physical activity. These studies started from what was already present in existing public open spaces in order to reveal which characteristics were important or associated with public open space use and physical activity at public open spaces. This could be considered as a limitation of the design of these studies. In chapter 4.1 on the other hand, another approach (i.e., conjoint analysis) was used in order to define which public open space characteristics were preferred by adolescents. Conjoint analysis enables to study the (combinations of) characteristics of POS without these characteristics being present at a POS.

2.3.1. FEATURES

MAN MADE FEATURES

The review included in chapter 3.1 revealed that the presence of sport activity zones (such as walking paths, BMX trails or sport fields) was positively associated with public open space visitation. The association between sport activity zones and physical activity was less straightforward as three studies found no associations and four did find a positive association between the presence of sport activity zones and physical activity at public open spaces. However, it is most likely that these inconsistent results were due to differences in measurement methods. Additionally, chapters 3.1 and 3.2 showed that qualitative studies indicate that sport activity zones, and especially soccer fields, are of utmost importance for adolescents' public open space visitation and physical activity. On the other hand, sport activity zones that require expensive equipment such as badminton fields were rarely used as participants often lacked equipment. This could be overcome by installing a "game library" where sport equipment such as badminton racquets can be lend out. Furthermore, sport fields were ranked as the third most important park characteristic for park visitation and park-based physical activity in chapter 4.1.

In our study using manipulated photographs (chapter 4.1) outdoor fitness equipment was the second most important park characteristic among adolescents for park visitation and physical activity. This indicates that the instalment of outdoor fitness equipment could encourage

physical activity in parks. This is supported by a natural experiment from the US where the instalment of outdoor fitness equipment in twelve parks was related to an increase in physical activity levels among users of all ages [28]. However, in a Danish study, contradicting results were found as they observed more users at public open spaces that provided opportunities for active play and games compared to public open spaces that provided opportunities for individual physical activity (such as outdoor fitness equipment). Therefore, they concluded that socializing and playing were more important and outdoor fitness equipment could not be the best choice for increasing physical activity levels as they were used less often. However, in this Danish study most observed public open space users were children and the outdoor fitness equipment was intended for adolescents, which could have elicited the lower level of usage. It should also be mentioned that 90% of the public open space users observed at the outdoor fitness equipment were observed in vigorous-intensity physical activity [29].

Another feature associated with public open space visitation identified in the systematic literature review was the presence of playgrounds (chapter 3.1). However, based on our qualitative studies (chapter 3.1 and 3.2) it could be concluded that these playgrounds had to be adventurous and age-appropriate in order to be attractive. Additionally, our photo-experiments revealed that for park-based physical activity, a park with a playground and outdoor fitness equipment was perceived more attractive than a park with solely outdoor fitness equipment.

NATURAL FEATURES

Besides man made features, also natural features such as the amount of trees and greenery were examined in this doctoral thesis. Based on the systematic literature review included in this doctoral thesis, naturalness and greenery at public open spaces appeared to be associated with public open space visitation and physical activity. In chapter 3.1, overall greenness, grassy areas, treed areas and number of trees, were associated with public open space visitation and physical activity, whereas no associations were found for the presence of meadows, tree canopy area and vegetation with physical activity at public open spaces. The photo-experiments indicated that parks with lots of greenery were preferred over a park with less greenery. However, despite the fact that lots of greenery was preferred, the amount of trees and plants was only ranked 7th in our photo-experiment. Additionally, in chapter 2.1 it was found that densely wooded park areas were the least often used park areas and it emerged

from chapter 3 that secluded areas were discouraging for public open space use. This indicates that the presence of trees and greenery is only associated with public open space use when an open view is ensured (i.e., no secluded areas). Furthermore, it is important to notice that in southern countries, trees can be important to provide shade. In more Northern countries the provision of shade is probably not perceived as necessary.

SUPPORTING AMENITIES

The systematic literature review and qualitative study (Chapter 3.1 and 3.2) included in this doctoral thesis indicated that adolescents are attracted to visit and use a public open space for physical activity when supporting amenities such as toilets, shelters, BBQ areas or picnic areas are present. However, limited evidence was found for such an association in our systematic literature review of quantitative studies (chapter 3.1) and in the photo-experiments (chapter 4.1). Some associations were found for shelters, toilets, BBQ areas and picnic areas and public open space visitation in the systematic literature review. It was not surprising that no associations were found for these amenities with physical activity, as these are amenities that are likely to elicit sedentary behaviours. The photo-experiments identified benches and drinking fountains as the two least important characteristics for park visitation and physical activity.

2.3.2.CONDITION

Maintenance of the public open spaces emerged from the walk along interviews and qualitative systematic literature review, as an important factor for public open space visitation and physical activity. Additionally, in chapter 4.1, maintenance of the park was identified as the most important park characteristic for park visitation and physical activity. However, in the systematic literature review only two studies were included that studied objectively-measured park maintenance. One study reported a positive association whereas the other found no association. A possible explanation may be that maintenance is subject to personal opinions and, therefore, difficult to measure using objective measurements. Furthermore, in the photo experiments, maintenance included three factors (presence of graffiti, presence of garbage and maintenance of the grass) which could have made this characteristic more notable. The maintenance of a public open space can influence attractiveness of a public open space in different ways. For example, the qualitative study showed that graffiti and evidence of drug use (e.g., syringes lying around) suggested the presence of undesirable users, broken

features could lead to injuries and when sport fields are covered in glass or rocks, participants first had to tidy up before using the field.

2.3.3.SOCIAL ENVIRONMENTAL CHARACTERISTICS

Based on the qualitative research in chapter 3.2, other public open space users were identified as very important for public open space visitation and physical activity. It emerged from the interviews that the presence of undesirable users (older adolescents, drug users, homeless people) was a deterrent for public open space visitation and physical activity, whereas the presence of active peers made public open spaces more attractive for physical activity and visitation. Fear from strangers or feeling less safe due to the presence of strangers is often referred to as “stranger danger”. Many adolescents express concerns about strangers (especially girls) [30,31], however, not many studies have looked into the associations between the presence of strangers and physical activity. In a study among 10– to 12-year-old children no associations were found between parental concern about strangers and walking and cycling levels among the children [30]. In another study, no associations were found between adolescents’ concerns about strangers and walking and cycling levels in the neighbourhood [31]. In chapter 4.1 it was found that adolescents prefer parks without homeless people. However, this was only the fifth most important park characteristic for park visitation and sixth for park physical activity.

The presence of peers was the fourth most important park characteristic for park visitation and physical activity (chapter 4.1) and it emerged from the walk-along interviews as a very important factor for public open space visitation and physical activity (chapter 3.2). Similar results were found in previous research; Brazilian adolescents (aged 14-19 years) and Portuguese boys (aged 12-18 years) living in neighbourhoods where other adolescents were physically active, were more likely to be physically active [32,33]. Furthermore, parks where peers were physically active were preferred over parks with sedentary peers which was preferred over a park without peers for park visitation. Whilst for park physical activity, a park with physically active peers was perceived better than a park without peers, which was preferred over a park with sedentary peers (chapter 4.1). These findings are supported by a systematic literature review on the role of peers for physical activity, where it was concluded that peer support and the presence of peers and friends was associated with higher physical activity levels among youth [34].

However, the presence of older adolescents has been identified (in the qualitative study in chapter 3.2) as a deterrent for physical activity at public open spaces. Participants often indicated that older adolescents (16+) bullied them or did not allow them to play along. In previous qualitative studies, similar results were found [35,36], whilst an Australian quantitative study did not find an association between 13-year-old adolescents' concern about older youth and walking and cycling in their neighbourhood [31]. A possible strategy to counteract this phenomenon may be to regularly organise activities at public open spaces where youth of all ages are active together. It has been shown that organising activities in the neighbourhood may increase social cohesion, connectedness among the inhabitants and solidarity among groups [37]. Another social issue that arose from our research was the conflict between (older) adults and youth at public open spaces. Adults often complained about ball games or noise (mostly at public open spaces where bars with outdoor terraces were present), and at some public open spaces ball games were forbidden (Chapter 3.1 and 3.2). This made adolescents feel excluded from the society and discouraged them to use that specific public open space. This phenomenon, where youth perceive that they are excluded from society, has been described before [38,39]. Adults often consider public open space as an 'adult' territory and the presence of youth is frequently considered as a problem because they use the public open space in a way that is considered as "inappropriate" by adults [38,39]. New laws and regulations are often developed (e.g., curfews) to guide youth into engaging in more suitable behaviours instead of considering them as full-fledged citizens.

A participatory approach (where citizens are involved in the design and management of the public open space), could help overcome some of these social issues by increasing community and civic engagement [40]. This approach is described more in detail in section 4 and 6 of the general discussion.

2.3.4. ARE OTHER PUBLIC OPEN SPACE CHARACTERISTICS IMPORTANT FOR PUBLIC OPEN SPACE VISITATION COMPARED TO PHYSICAL ACTIVITY AT PUBLIC OPEN SPACES?

A noteworthy finding from the qualitative research (chapter 3.2) and photo experiments (chapter 4.1) was that few differences were found between the characteristics of public open spaces that made them attractive for visitation and for physical activity. This implicates that improving the characteristics defined in this doctoral thesis, could increase public open space visitation and physical activity simultaneously.

2.3.5.CONCLUSION

From the studies included in this doctoral thesis, we can conclude that public open spaces should contain sport activity zones such as a soccer field and age appropriate playgrounds in order to be attractive for adolescents to visit and for physical activity. Additionally, parks with a sport field, playground and outdoor fitness equipment were preferred over parks without these facilities. From our results we can conclude that public open spaces with greenery are preferred over public open spaces with less greenery. However, greenery was less important compared to sport activity zones. Additionally, supporting amenities are not the most important features for public open space visitation and physical activity, however, they could contribute to the overall experience at the public open space. Nevertheless, attention should be paid as these could elicit sedentary behaviour. Furthermore, our results emphasize the importance of a regular and profound maintenance system that includes regular garbage collection, graffiti removal, maintenance of greenery and regular repairs of broken features. The presence of other people (undesirable users and peers) at public open spaces could be an important issue, which needs attention in future interventions. Teach adolescents how to handle confrontations with undesirable users could be a useful strategy to decrease their fear from strangers. The fact that a park without peers was preferred over a park with sedentary peers for physical activity in the park was a novel insight, as to our knowledge, no studies have looked into the association between the presence of sedentary peers and physical activity in parks.

3. STRENGTHS AND LIMITATIONS

In this section the main strengths and limitations of this doctoral thesis will be discussed.

Some overall strengths of this thesis have to be acknowledged.

- A major strength within this doctoral thesis was the broad definition that was used to define public open spaces. This led to the inclusion of several kinds of public open spaces, such as parks, squares, streets and vacant lots. Previous studies often focussed on parks, excluding all physical activity that occurred in other public open space locations.
- The target population of this doctoral thesis was adolescents, which is an understudied population in public open space research. It has been acknowledged that most adolescents do not comply with the physical activity guidelines and physical activity behaviour tracks from adolescence into adulthood. Therefore, interventions to promote physical activity among adolescents are warranted and the research presented in this doctoral thesis can help to inform future interventions.
- One of the major strengths was the focus on public open spaces. Public open spaces are present in almost all communities, are freely accessible to all people and can reach the whole population. Public open spaces can be important settings for physical activity and can have other benefits such as the provision of green space which is associated with mental health. Research on the characteristics of public open spaces associated with public open space visitation and physical activity was limited at the start of this doctoral thesis.
- Both public open space visitation and physical activity at public open spaces were included in this doctoral thesis and ensured a more comprehensive view on the use of public open spaces. The characteristics of public open spaces that attract adolescents to visit, may differ from the characteristics that attract adolescents for physical activity, therefore, these two behaviours should be investigated separately.
- A wide range of methods including systematic literature reviews, qualitative and quantitative studies based on surveys, audits, observations, accelerometry and GPS data and photograph experiments were used in this PhD-project. When multiple methods are used, different perspectives are created, and additionally, each method

has its own advantages and disadvantages. By using multiple methods, it is possible to get a more comprehensive view on the subject.

- Within this doctoral thesis, both physical and social environmental characteristics of public open spaces were included. This provides a more comprehensive view on the characteristics related to the use of public open spaces compared to previous research which often solely included physical environmental characteristics.
- In the studies included in this thesis, public open spaces that were actually used by the participants were the focus of the study. In most other research, questionnaires asking about the neighbourhood environment or overall neighbourhood measures were used to acquire a measure of public open space characteristics associated with physical activity. However, these may not be the actual public open spaces that are used by the participants. This phenomenon is called the Modifiable Arial Unit Problem (MAUP) and was avoided in this doctoral thesis by assessing the public open spaces that are actually used.
- For the walk-along study (chapter 3.2) and the review (chapter 3.1), the environmental characteristics were categorized in the same categories as was done in previous research [11,41]. This increased the comparability of our results with previous research findings.
- This doctoral thesis adds upon the existing research that predominantly originates from the US and Australia by providing a European perspective.

Next to the strengths, some limitations have to be taken into account when interpreting the results.

- A main limitation of this doctoral thesis was the cross-sectional design of the studies and the fact that no natural experiments were performed. A natural experiment was planned within this doctoral thesis, however, due to organisational difficulties and changes is the planning, this was cancelled. A natural experiment allows to investigate causal relationships between changes in the environment and behaviour at public open spaces. The photo-experiments allowed to identify the most important characteristics of public open spaces associated with the attractiveness of a park. However, natural experiments are needed in order to confirm whether changing these characteristics will actually change physical activity behaviour.

- Different indicators (i.e. FAS score, parental occupation or parental educational level) were used to define SES across the studies in this doctoral thesis, which may have led to inconsistent findings. Additionally, many participants were not able to report parental occupation or educational level, leading to missing values concerning SES.
- Within this doctoral thesis it was attempted to focus on low SES youth. However, the amount of low SES youth participating in the studies included in this doctoral thesis was rather limited (i.e. chapter 3.2: 62.5% of the participant had a low SES according to the occupation of the parents; chapter 2.2: 22.5% of the participants had low SES according to the educational level of the participants; chapter 4.1: 36.2% of the participants had low-medium SES according to the FAS and 22.4% according to the educational level of the parents). Future studies could prevent low representation of low SES youth in their sample by oversampling at low SES schools."
- Some of the studies in this doctoral thesis used a questionnaire to assess physical activity. Self-report measures of physical activity may be susceptible to over reporting due to social desirability bias [42,43].
- Within this doctoral thesis, a socio ecological approach was used. However, no policy related characteristics were included in the studies. Research on the role that policies may have on the use of public open spaces for physical activity is currently lacking and is necessary for a comprehensive understanding of the characteristics influencing adolescents' public open space use and physical activity.
- The results of the studies included in this doctoral thesis may have low generalizability as they were all conducted in Flanders. Additionally, in chapter 2.1, only two parks were included and in chapter 2.3 only two days of accelerometer and GPS data were included, which also contributed to low generalizability. Therefore, results have to be interpreted with caution and additional research is needed in other European and non-European countries to confirm current findings and identify possible cultural differences.

4. PRACTICAL IMPLICATIONS

Based on the research included in this doctoral thesis, some practical implications can be formulated.

In some studies performed in this doctoral thesis, it was found that girls and females were less likely to visit and be physically active at public open spaces compared to men. This implicates that future interventions should target girls and women specifically and public open spaces should be designed to attract more females. Previous research revealed that adolescent girls mostly used public open spaces for socializing activities [44] and engage mainly in individual, non-competitive, 'fun' activities such as dancing, running or netball [16-18]. Urban planners should take this into account when developing new public open spaces, by providing places within the public open space that are suitable for socializing and for individual, non-competitive and fun physical activities.

Associations of ethnicity and education with time spent and physical activity at public open spaces have been identified in this doctoral thesis. This indicates that the use of public open spaces could be culturally inspired and be more or less imbedded into the habits of specific population groups. These are very important results, as non-white and low educated adolescents are groups at risk for inactivity [9,23]. Creating interventions at public open spaces can thus reach those groups that most need it. In Flanders (Belgium) already some initiatives at public open spaces exist, which are united under the name "Buurtsport" (i.e. neighbourhood sports) [21]. Our results support these initiatives and call for the continuation and expansion.

Chapter 4.1 revealed that adolescents prefer public open spaces that are well maintained, with sport fields, outdoor fitness equipment and playgrounds. Public open space administrators (mostly city councils) should develop a regular and profound maintenance system, that makes sure public open spaces and the facilities are clean (i.e. regular garbage collection, graffiti removal) and facilities are repaired or replaced when needed. Additionally, public open spaces can be made more attractive for visitation and physical activity among adolescents by providing sport fields, outdoor fitness equipment and playgrounds. These are rather small modifications (compared to total public open space development or renovations) that could encourage public open space visitation and physical activity among adolescents.

From the systematic literature review in chapter 3.1 it appeared that most public open space features (mostly playgrounds) were designed for younger children, whilst adolescents prefer more challenging features. Future urban planners should thus create more challenging, but safe, public open spaces with age appropriate facilities such as high slides, trampolines or high swings.

Different park areas were shown to attract differing numbers of park users and to elicit different physical activity levels in parks (i.e. densely wooded areas were rarely visited or used for physical activity). Hence, urban planners should avoid combining different park areas that elicit sedentary behaviour or that attract only few park users. Furthermore, densely wooded forest may not be the best way to shape a park, as densely wooded areas could reduce feelings of safety due to low visibility. Increasing visibility in wooded areas by providing trails and reducing low shrubbery could increase the use of these wooded areas without making major changes or big investments.

Participants in the qualitative study mentioned to use the public open spaces close to home, school or public transportation stops more often. Therefore, it could be hypothesized that prioritizing the renewal of public open spaces in neighbourhoods with many adolescents or close to secondary schools and public transportation stops/stations could be beneficial.

As the amount of public open space is currently limited and is expected to reduce due to the densification of cities, creating new public open spaces is probably not very realistic. However, other possibilities exist. Most European historical cities have many small public parks and plazas spread through the city, and our observational study showed that many park users used the park to cycle through to other destinations. Therefore, connecting these small parks by trails could increase physical activity levels and may be feasible in most European cities. However, cycling is often forbidden in parks. Policy makers should take this into account and assure at least one cycle lane in each park.

Currently, indoor sport facilities are often fully booked, limiting schools and sport clubs in their provision of organized sports. Public open spaces and parks could provide a suitable alternative for schools and sport clubs. Existing activities could be relocated and the sport offer could be extended. However, this would also pose some difficulties concerning the weather and the provision of specific features and equipment. Furthermore, it was found that

parks where other adolescents were physically active were preferred over parks without peers or with sedentary peers, indicating that the use of public open spaces by schools and sport clubs could have a facilitating effect on public open space visitation and physical activity by creating a supportive environment and by acquainting children and adolescents with public open spaces.

When developing interventions or designing new public open spaces, the use of a participatory or co-creation approach should be considered. Such an approach consists of a process of reflection and action, carried out with and by local people rather than on them [45]. It has been shown that such an approach results in identifying culturally relevant themes, increased relevance for all people involved and overcoming social barriers during data collection. Other benefits are higher capacity of the community stakeholders and researchers and more possibilities to sustain project goals beyond funded time frames [46]. The most important benefit is the increased involvement and sense of responsibility from the community itself when inhabitants are involved in the design and development of new public open spaces [47]. Additionally, such an approach can contribute to social norms concerning physical activity behaviours, which is especially important in cultures that may discourage physical activity (e.g., Muslim girls) [40].

5. EXAMPLES OF EXISTING INITIATIVES

5.1. CRUYFF COURTS (MECHELEN, FLANDERS, BELGIUM)

The Cruyff foundation was founded by former Dutch football player Johan Cruyff. The foundation supports sport and play projects for youth around the world. The "Cruyff courts" are artificial soccer fields that have been installed all around the world (15 countries so far) with the aim to increase physical activity levels among youth. The courts also function as a meeting spot for youth where they can play and practice sport safely. Sports is used as a means to increase respect, social cohesion, integration and health in the neighbourhood.

Figure 1: Cruyff courts Mechelen

5.2. URBAN SPORTS AND CULTURE HALL (ANTWERP, FLANDERS)

The city of Antwerp opens up their sports hall for all children and adolescents during summer. In collaboration with youth workers, a range of new, urban sports (e.g., parcours, free running, urban dance) is offered. Adolescents can practice sports independently or can follow workshops, attend demonstrations or dance-battles. Adolescents indicated that they use the sport hall because it is free and enables activities that are not possible on the streets.

Figure 2: Urban sports and culture hall Antwerp

5.3. INITIATIVES AT PUBLIC TRANSPORTATION STOPS AND STATIONS

5.3.1. BIKE DESKS AT BRUSSELS SOUTH RAILWAY STATION AND BRUSSELS AIRPORT

In Brussels South Railway station and Brussel National Airport, cycling desks with a charging feature are present. These are used by people who have to wait for their train or flight. In an observational study, where the use of these bike-desks was observed for 3 days, it was found that 135 people used the bike desk and mean cycling time was 15.3 minutes. Of these 135, 100 completed a questionnaire which indicated that 83% of the people who were surveyed used the bike because of the charging feature, 20% used it because it was fun and a good distraction while waiting and 12% used it for health reasons [48].

Figure 3: Bike desks at Brussels Airport

5.3.2. SWINGS AT PROMENADE DES ARTISTES, QUARTIER DES SPECTACLES, MONTRÉAL

Another creative example can be found in Montreal, Canada where 21 swings have been installed next to the bus station. Each of these swings produces the sound of a music

instrument. When swinging together, people (of all ages) can produce music [49].

Figure 4: Swings at Promenade des artistes, Quartier des spectacles, Montréal

5.3.3. BUS STOPS IN SAN FRANSISCO

In 2015 in San Francisco, a new bus stop was installed that was created with the aim to stimulate activity while waiting for the bus. The bus stop was designed such that it could be used as a climbing wall, children's play space, meditation space and a regular bus stop [50].

Figure 5: Active rest bus stop, San Francisco

6. RECOMMENDATIONS FOR FURTHER RESEARCH

This research identified some shortcomings in the literature and highlights the need for more research on the use of public open spaces in Europe and among adolescents. Some suggestions for future research are listed below.

In the first part of this doctoral thesis, the need for a pan-European surveillance system to monitor physical activity levels was identified. Such surveillance system could help making policy decisions for the development of effective physical activity promotion interventions by detecting trends and providing reliable prevalence data. This surveillance system should use standardized objective physical activity measurement methods supported by subjective measurement methods to measure physical activity behaviour. Both objective and self-report measurement methods have advantages and disadvantages [42,43]. It is not possible to obtain context-specific physical activity measurements using objective measurement methods. Therefore, objective measurements should be complemented with subjective data. Additionally, there is a need for accelerometer data that are cleaned, reduced and processed in the same way. This can be done by building on previous work, for example the International Children's Accelerometry Database (ICAD) project pooled individual accelerometer data files of children and cleaned, reduced and processed it using standardized methods [51].

We call for more research on the use and the characteristics of public open spaces related to the use of public open spaces as the evidence remains relatively limited. Most research concerning the use of public open spaces and characteristics of public open spaces associated with public open space visitation and physical activity originates from the US and Australia. Therefore, additional research from European countries is warranted as differences in the use of public open spaces can exist between countries.

Currently, parks are the most frequently studied public open space location. Future studies should try to include other (less-conventional) public open spaces suitable for physical activity (such as squares) in order to provide a more comprehensive view on the use and characteristics of public open spaces (and not only parks). It has to be acknowledged that not all public open spaces are suitable for physical activity. For example, it may not be very feasible to target public transportation stops/stations for physical activity interventions; however, some examples exist of public transportation stops that have been designed to encourage

physical activity (see General discussion: Chapter 5). Furthermore, analyses should be done for each location separately as specific locations may be used differently and in order to identify whether the same characteristics are important for different locations.

Most studies have included features for more traditional sports (i.e., sport fields for soccer or basketball). It would be interesting to gain insight into the impact of features for less conventional sports such as “parcours”, or skateboarding on physical activity levels among youth, in future studies. In this doctoral thesis, policy related characteristics were not included; however, research concerning policy related factors associated with physical activity at public open spaces could be relevant.

It has been shown that differences exist in the characteristics of public open spaces between high and low SES neighbourhoods [52-54]. Additionally, differences in maintenance and available facilities between high and low SES neighbourhoods are also present [15,55]. Furthermore, it could be expected that low SES youth engage in different activities compared to high SES youth (e.g., low SES youth may not have expensive equipment to play tennis and would rather play soccer). Therefore, future research should examine the differences between high and low SES youth concerning public open space use and physical activity.

GPS devices are only recently being used in public health research. More studies using GPS devices and accelerometers are needed as this method allows to objectively measure location-specific physical activity. Preferably, this should be done in combination with some subjective input in order to gain insight into the context of public open space visitation. However, when using GPS devices in combination with personal interviews, the data processing is very time consuming. Therefore, we recommend to use a mobile application with ecological momentary assessment in order to capture the context of public open space use [56]. Additionally, this will allow to collect data for a longer period of time. Furthermore, many studies have evaluated the associations between public open space characteristics within the neighbourhood wherein adolescents live or closest to home. However, adolescents may not use the public open spaces closest to home [57].

Almost all research focusses on urban public open spaces, however, also in rural areas, public open spaces can be important locations for physical activity. Some research has indicated that differences exist in the provision and quality of urban and rural public open spaces [58,59].

Therefore, studies concerning public open spaces in rural areas should be undertaken to identify differences between urban and rural public open space use and characteristics associated with public open space use and physical activity.

The results of our photo-experiment should be confirmed by performing natural experiments in order to identify the public open space characteristics that actually influence physical activity behaviour at public open spaces and public open space visitation. Natural experiments are highly recommended to identify causal relationships between characteristics of public open spaces and physical activity. A natural experiment includes changes to the real environment in which people live through physical changes that are implemented by city planners. However, these are often difficult to carry out due to organisational and financial challenges [60]. In this doctoral thesis no causal relationship could be identified and therefore we could only identify possible important characteristics. Such natural experiments can benefit from collaborations between researchers and the city councils. Public open space renovations are good opportunities for such experiments, as the environmental changes can be executed by the city council, while the researchers have the opportunity to investigate the use of these public open spaces before and after renovations. Such natural experiments are often hard to conduct because of organisational challenges such as changes to timelines or budget for implementation of infrastructure [60]. Within this doctoral project it was attempted to perform a natural experiment, however due to changes in the timeline (of the city council) this has not yet been executed. Furthermore, if researchers are involved in the design of the public open space, it is possible to include specific public open space characteristics of which we know they could increase visitation and physical activity. Such collaborations could be facilitated by creating a publicly accessible database of all planned public open space renovations.

Using manipulated photographs is an efficient way to manipulate public open space characteristics without actually having to change the real environment. Future research using manipulated photographs should study whether there are subgroups that have different preferences (e.g., low SES or girls), and whether interaction effects exist between public open space characteristics. Additionally, the photo-experiments should be repeated with other characteristics and other public open space locations (such as squares or streets). For example, when the distance to a public open space would be added as a public open space

characteristic, the characteristics that would make adolescents travel further in order to visit a public open space could be identified. Additionally, the GPS study revealed that the company during a public open space visit may influence time spent at public open spaces. Therefore, also company should be included in future photo-experiments. However, this method still comprises some methodological limitations, such as the inability to include sound. Therefore, we recommend to develop virtual experiments using virtual reality programs in order to create an experience as realistic as possible for the participants.

Within this doctoral thesis, none of the included studies used a participatory or "co-creation" approach. However, there are multiple examples of the planning and design of public open spaces where youth were involved in one or more phases of the developmental process [61-64]. Such an approach poses multiple benefits such as: ensure culturally and logistically appropriate research, generate professional capacity and competence in stakeholder groups, result in productive conflicts followed by useful negotiation, increase the quality of outputs and outcomes over time, increase the sustainability of project goals beyond funded time frames and during gaps in external funding, and create system changes and new unanticipated projects and activities [46]. Therefore, we recommend the use of this approach in future research concerning the renovation and development of new and existing public open spaces and for planning and design of public open spaces.

Finally, this doctoral thesis revealed that the characteristics that were identified as important for public open space visitation were not very different from the characteristics important for physical activity at public open spaces. However, we recommend for future research to investigate these behaviours separately as these could be influenced by different characteristics.

7. CONCLUSION

Physical activity levels among adolescents in Europe are low and interventions for physical activity promotion are needed. This doctoral thesis revealed that public open spaces are currently not often used by adolescents and parks not often by the overall population. Furthermore, many public open space characteristics that are associated with public open space visitation and physical activity have been identified in this doctoral thesis. From the studies included in this doctoral thesis, we can conclude that the installation of sport fields, age appropriate playgrounds and outdoor fitness equipment increases the attractiveness of public open spaces for visitation and physical activity among adolescents. Additionally, the presence of peers and undesirable users also determines the attractiveness of public open spaces. Furthermore, public open space administrators should ensure a good and regular maintenance system in order to keep public open spaces clean and safe. Future natural experiments should be conducted to confirm these associations.

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9. OVERVIEW OF A1 PUBLICATIONS

FIRST AUTHORSHIP

Linde Van Hecke, Benedicte Deforche, Delfien Van Dyck, Ilse De Bourdeaudhuij, Jenny Veitch, Jelle Van Cauwenberg. Social and Physical Environmental Factors Influencing Adolescents' Physical Activity in Urban Public Open Spaces: A Qualitative Study Using Walk-Along Interviews. In: PLoS ONE, Vol. 11, No. 5, 2016.

Linde Van Hecke, Anne Loyen, Maïté Verloigne, Hidde P. van der Ploeg, Jeroen Lakerveld, Johannes Brug, Ilse De Bourdeaudhuij, Ulf Ekelund, Alan Donnelly, Ingrid Hendriksen, Benedicte Deforche, on behalf of the DEDIPAC consortium. Variation in population levels of physical activity in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC. International Journal of Behavioral Nutrition and Physical Activity, Vol. 13, No. 1, 2016, p. 70.

Linde Van Hecke, Jelle Van Cauwenberg, Peter Clarys, Delfien Van Dyck, Jenny Veitch, Benedicte Deforche. Active Use of Parks in Flanders (Belgium): An Exploratory Observational Study. International Journal of Environmental Research and Public Health, Vol 14, No. 1, 2017, p. 30-35.

Linde Van Hecke, Hannah Verhoeven, Peter Clarys, Delfien Van Dyck, Nico Vandeweghe, Tim Baert, Benedicte Deforche, Jelle Van Cauwenberg. Factors related with public open space use among adolescents: a study using GPS devices and accelerometers. International Journal of Health Geographics, Vol 17. No. 3, 2018

Linde Van Hecke, Ariane Ghekiere, Jenny Veitch, Jelle Van Cauwenberg, Peter Clarys, Delfien Van Dyck, Benedicte Deforche. Public open space characteristics influencing adolescents' use and physical activity: a systematic literature review of qualitative and quantitative studies. Under review in Health and Place

Linde Van Hecke, Ariane Ghekiere, Jelle Van Cauwenberg, Jenny Veitch, Ilse De Bourdeaudhuij, Delfien Van Dyck, Peter Clarys, Nico Van de Weghe, Benedicte Deforche. Park characteristics preferred for adolescent park visitation and physical activity: a choice-based conjoint analysis using Manipulated photographs. Under review in Landscape and Urban Planning

CO AUTHORSHIP

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10. LIST OF ABBREVIATIONS

- MET = Metabolic Equivalent of Task
- HBSC study = Health Behaviour in school aged Children-study
- GPS = Global Positioning System
- SES = Socio-Economic Status
- GIS = Geographical Information Systems
- US = United States
- DEDIPAC = DEterminants of DIet and Physical Activity
- EAPRS = Environmental Assessment of Public Recreation Spaces
- SOPARC = The System for Observing Play and Recreations in Communities
- CBC = Choice-based conjoint
- MAUP = Modifiable Arial Unit Problem

11.CURRICULUM VITAE

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Name	Linde Van Hecke
Date of birth	January 6th 1990
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Education

2014-2017 PhD in Health sciences, Ghent University, Department of Public Health
PhD in Physical education and movement sciences, Vrije Universiteit Brussel, Department of Movement and Sport Sciences
PhD Thesis: The role of public open spaces for physical activity promotion among adolescents

2011-2013 Master of Science in Physical education and movement sciences, Vrije Universiteit Brussel
Specialisation: Sport management
Specialisation: Fitness and Health
Master Thesis: Predictors of weight gain among freshmen at university.

2011-2013 Specific teacher education, Vrije Universiteit Brussel

2008-2011 Bachelor of science in Physical education and movement sciences, Vrije Universiteit Brussel

Additional Training

2017 Course Personal Effectiveness

2016 Course linear mixed models in SPSS
From PhD to Job Market: "Believing in first Mover Advantages"
Workshop "How to create engaging research presentations and posters"

2015 Workshop "Effective Scientific communication"
Specialist course "Statistical analyses in R for movement and health scientists"
FLAMES workshop "Power and sample size"
Course "Regression analyse"

2014 Workshop "Participatory Health research" Prof. Michael Wright
Workshop "Navigating in the ocean of biomedical information"
Workshop "Effective graphical displays"
Course "Intervention mapping" Gerjo Kok

Scientific contributions

International A1 publications

Linde Van Hecke, Benedicte Deforche, Delfien Van Dyck, Ilse De Bourdeaudhuij, Jenny Veitch, Jelle Van Cauwenberg. Social and Physical Environmental Factors Influencing Adolescents' Physical Activity in Urban Public Open Spaces: A Qualitative Study Using Walk-Along Interviews. In: PLoS ONE, Vol. 11, No. 5, 2016.

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Linde Van Hecke, Ariane Ghekiere, Jelle Van Cauwenberg, Jenny Veitch, Ilse De Bourdeaudhuij, Delfien Van Dyck, Peter Clarys, Nico Van de Weghe, Benedicte Deforche. Park characteristics preferred for adolescent park visitation and physical activity: a choice-based conjoint analysis using Manipulated photographs. Under review in Landscape and Urban Planning

Oral presentations at international conferences

"Social and physical environmental factors influencing adolescents' physical activity in urban public open spaces: a qualitative study using walk-along interviews" Annual meeting of the International Society of Behavioural nutrition and Physical activity, June 2015, Edinburgh, Scotland.

"Social and physical environmental factors influencing adolescents' physical activity in urban public open spaces: a qualitative study using walk-along interviews" Annual Cambridge-Ghent-Amsterdam meeting, April 2015, Amsterdam, The Netherlands

"Variation in population levels of physical activity in European children and adolescents: a systematic review within DEDIPAC" Annual meeting of the International Society of Behavioural nutrition and Physical activity, June 2016, Cape town, South-Africa.

"Park characteristics preferred for adolescent park visitation and physical activity - A choice-based conjoint analysis using manipulated photographs" Annual meeting of the International Society of Behavioural nutrition and Physical activity, June 2017, Victoria, Canada.

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